PHYSICS LEVEL N
QUESTION BOOKLET

Code Number 42-03093-12 V.6
Printed in the United Arab Emirates

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Contents

PHYSICS Level N Question Booklet

Chapter 21:

Electric Charge and Electric Field

1. (a) State Coulomb's law and give its mathematical expression.

(b) Two point charges, $q_1 = -3.0$ nC and $q_2 = +5.0$ nC are separated by a distance of 2.0 cm. Find the magnitude of the electric force that q_1 exerts on q_2.

(c) Define electric field.

(1 mark)

2. (a) Find the magnitude of the electric field at a field point 4.0 m from a point charge $q = 2.0$ nC.

(b) The electric field caused by a certain charge at a distance 2.0 cm from the charge is 4.5×10^5 NC^{-1} away from the charge. What is the charge?

(1 mark)

3. (a) Find the distance from a charge of 16 nC where the electric field due to the charge has a magnitude of 4.0×10^4 NC^{-1}.

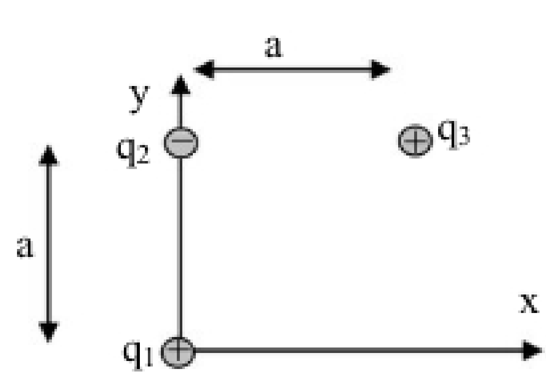
(b) A point charge $q = 6.00$ nC is located at the origin. What is the magnitude of the electric field vector at the point of coordinates (– 15.0 cm, – 20.0 cm)?

(1 mark)

4. Three charges lie along the x–axis as shown in the diagram. The positive charge $q_1 = 4.00$ μC is at $x = 4.00$ m, and the positive charge $q_2 = 8.00$ μC is at the origin. A negative charge q_3 is placed on the x–axis such that the resultant force on it is zero. What is the x–coordinate of q_3?

(1 mark)

5.



Consider three point charges located at the corners of a triangle, as shown in the diagram, where $q_1 = q_3 = 3.00$ μC, $q_2 = -8.00$ μC, and $a = 0.120$ m.

(a) Find the magnitude of the force $\mathbf{F_1}$ of q_1 on q_3.

(b) Find the magnitude of the force $\mathbf{F_2}$ of q_2 on q_3.

(c) What is the x–component of the resultant force on q_3?

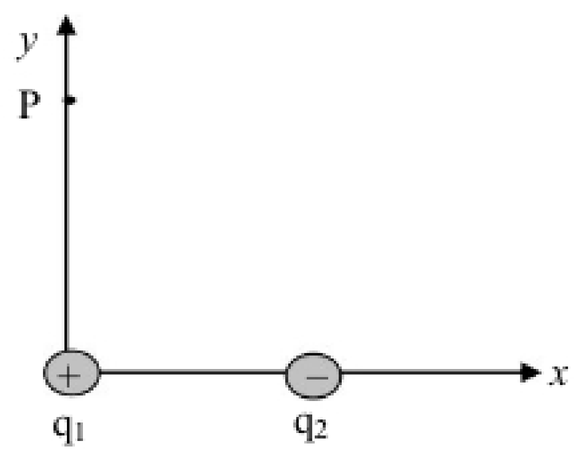
(d) What is the y–component of the resultant force on q_3?

(e) Find the magnitude of the resultant force on q_3.

(f) Calculate the angle the resultant force makes with the positive x–axis.

(2 marks)

6.



A charge $q_1 = 8.00\ \mu C$ is located at the origin, and a second charge $q_2 = -3.00\ \mu C$ is located on the x–axis 0.800 m from the origin, as shown in the diagram. Point P has coordinates (0, 0.600) m.

(a) Find the magnitude of the electric field at P due to q_1.

(b) Find the magnitude of the electric field at P due to q_2.

(c) What is the x–component of the resultant electric field at P?

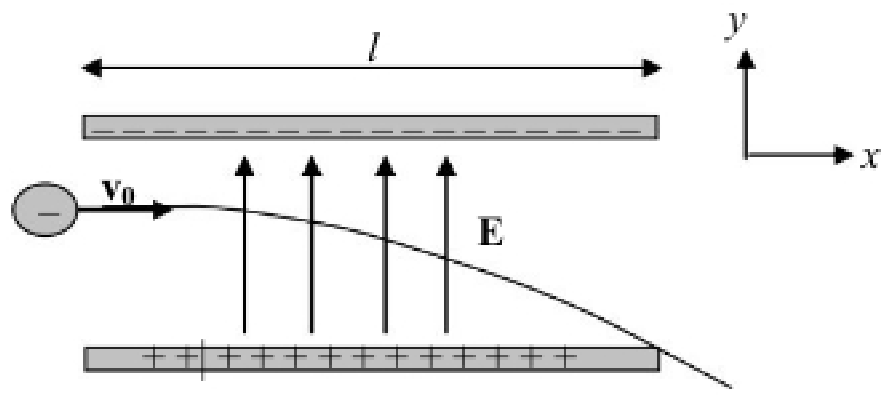
(d) What is the y–component of the resultant electric field at P?

(e) Find the magnitude of the resultant electric field at point P.

(f) Calculate the angle the resultant electric field makes with the positive x–axis.

(2 marks)

7.



An electron of mass 9.11×10^{-31} kg enters the region of a uniform electric field as shown in the diagram, with $v_0 = 2.00 \times 10^6$ m/s and E = 300 N/C. The width of the plates is $l = 0.250$ m.

(a) Find the acceleration of the electron while in the electric field.

(b) Find the time it takes the electron to travel through the region of the electric field.

(c) What is the vertical displacement y of the electron while it is in the electric field?

(d) Calculate the speed of the electron as it emerges from the electric field.

(2 marks)

8. (a) In a thundercloud there may be an electric charge of +30.0 C near the top and –30.0 C near the bottom. These charges are separated by approximately 3.00 km. Find the magnitude of the electric force between them.

(b) What are the magnitude and direction of the electric field that will balance the weight of three protons, of mass 1.67×10^{-27} kg each?

(1 mark)

9. A 45.0–g insulating sphere carries a charge Q = –40.0 μC and is suspended by a silk thread from a fixed point. An external electric field which is uniform and vertical downward is applied.

(a) The applied electric field has a magnitude of 2.00×10^3 N/C. What is the tension in the thread?

(b) The applied electric field holds the sphere in place above the fixed point of suspension, and the tension in the thread is 0.450 N. Find the magnitude of the electric field.

(1 mark)

Chapter 22:

Gauss's Law

1. (a) State Gauss's law in words and give its mathematical expression.

(b) When excess charge is placed on a solid conductor, where does it reside?

(c) Write the three forms of the general definition of electric flux.

(d) Give the expression of the magnitude of the electric field outside a charged conducting sphere.

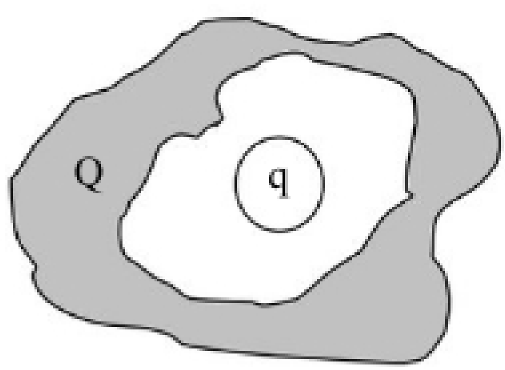
(1 mark)

2. (a) What Gaussian surface is used to find the electric field outside an infinitely long charged wire?

(b) What is the magnitude of the field of an infinite sheet of charge?

(c) What is the magnitude of the field between oppositely charged parallel conducting plates?

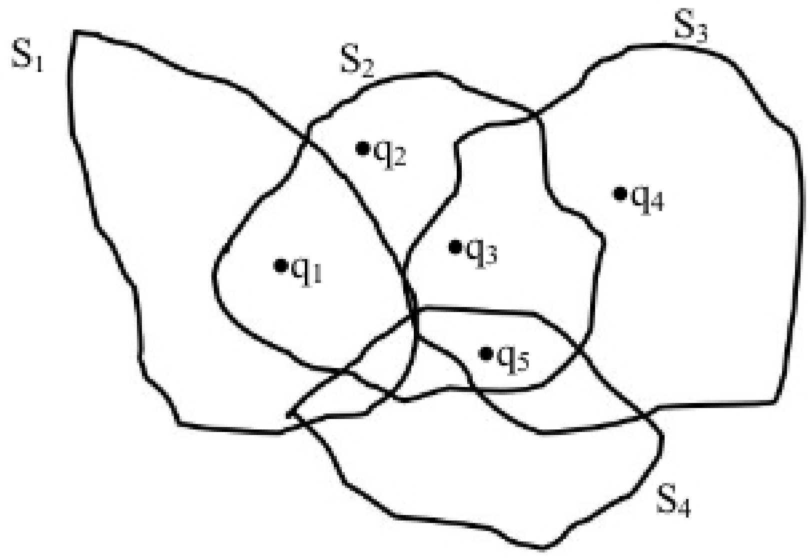
(d)



The shaded conductor shown in the figure carries a total charge of Q = +7.0 nC. The charge within the cavity, insulated from the conductor, is q = –2.0 nC. What is the charge on the inner surface of the conductor?

(1 mark)

3.



Four closed surfaces S_1 through S_4, together with the charges q_1, q_2, q_3, q_4 and q_5 are sketched in the figure. $q_1 = -4Q$, $q_2 = +Q$, $q_3 = -2Q$, $q_4 = -3Q$, $q_5 = -Q$

(a) Find the electric flux through surface S_1.

(b) Find the electric flux through surface S_2.

(c) Find the electric flux through surface S_3.

(d) Find the electric flux through surface S_4.

(1 mark)

4. (a) A point charge Q = 7.00 μC is located at the centre of a cube of side L = 0.150 m. Six other point charges, each carrying a charge q = –1.50 μC, are positioned symmetrically around Q, inside the cube. What is the electric flux through one face of the cube? (permittivity of free space = 8.85×10^{-12})

(b) The total electric flux through a closed surface in the shape of a cylinder is 4.80×10^4 Nm^2/C. What is the net charge within the cylinder? (permittivity of free space = 8.85×10^{-12})

(1 mark)

5. A thin conducting wire square plate 35.0 cm on a side lies in the *xy* plane. A total charge of 1.96×10^{-8} C is placed on the plate. (permittivity of free space = 8.85×10^{-12}).

(a) Find the charge density on the plate.

(b) What is the magnitude of the electric field just above the plate?

(1 mark)

6. A conducting spherical shell of radius 13.0 cm carries a net charge of 5.07 μC uniformly distributed on its surface.

(a) Find the magnitude of the electric field just outside the shell.

(b) Find the magnitude of the electric field inside the shell.

(c) What is the magnitude of the electric field at a point very far away from the shell?

(1 mark)

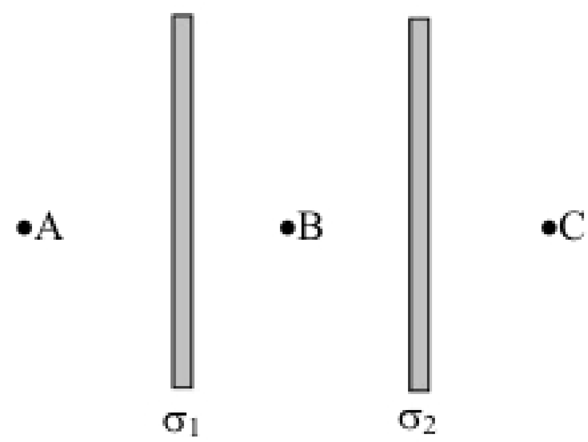
7. A conducting spherical shell having an inner radius of 5.00 cm and outer radius of 6.00 cm carries a net charge of 9.00 μC. If a +4.00 μC point charge is placed at the centre of the shell, determine the surface charge density on:

(a) the inner surface.

(b) the outer surface.

(1 mark)

8.



Two infinite, nonconducting sheets of charge are parallel to each other as shown in the figure.

(a) Both sheets have positive uniform charge densities $\sigma_1 = \sigma_2 = 5.31 \times 10^{-4}$ C/m^2. What is the electric field at point A?

(b) Both sheets have positive uniform charge densities $\sigma_1 = \sigma_2 = 5.31 \times 10^{-4}$ C/m^2. What is the electric field at point B?

(c) Both sheets have positive uniform charge densities $\sigma_1 = \sigma_2 = 5.31 \times 10^{-4}$ C/m^2. What is the electric field at point C?

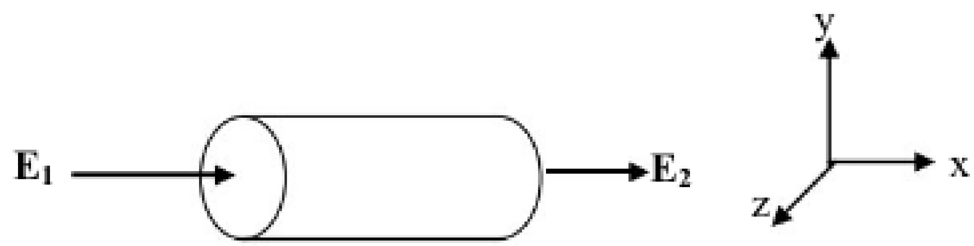
(d) The sheet on the left has a uniform surface density $\sigma_1 = 5.31 \times 10^{-4}$ C/m^2, and the one on the right has a uniform charge density $\sigma_2 = -5.31 \times 10^{-4}$ C/m^2. What is the electric field at point A?

(e) The sheet on the left has a uniform surface density $\sigma_1 = 5.31 \times 10^{-4}$ C/m^2, and the one on the right has a uniform charge density $\sigma_2 = -5.31 \times 10^{-4}$ C/m^2. What is the electric field at point B?

(f) The sheet on the left has a uniform surface density $\sigma_1 = 5.31 \times 10^{-4}$ C/m^2, and the one on the right has a uniform charge density $\sigma_2 = -5.31 \times 10^{-4}$ C/m^2. What is the electric field at point C?

(2 marks)

9.



A non–uniform electric field is directed along the x–axis at all points in space. The magnitude of the field varies with x, but not with respect to y and z. The axis of a cylindrical surface, 1.00 m long and 0.500 m in diameter, is aligned parallel to the x–axis. The electric fields $\mathbf{E}_1$ and $\mathbf{E}_2$, at the ends of the cylindrical surface, have magnitudes 5.00×10^3 N/C and 1.50×10^3 N/C respectively, and are directed as shown in the diagram.

(a) Find the electric flux entering the cylindrical surface at the left end.

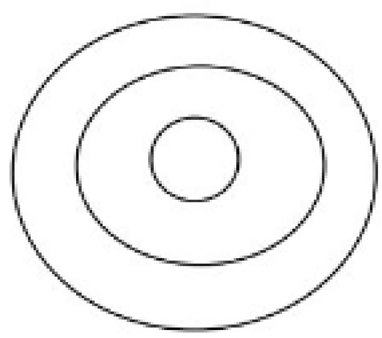
(b) Find the electric flux leaving the cylindrical surface at the right end.

(c) Find the net electric flux through the cylindrical surface.

(d) What is the net charge enclosed by the cylindrical surface?

(2 marks)

10.



Three hollow, concentric spherical conductors are charged as follows: The inner sphere carries –2Q, the middle sphere carries +3Q and the outer sphere carries –Q.

(a) Find the charge on the outer surface of the middle sphere.

(b) Find the charge on the outer surface of the outer sphere.

(1 mark)

Chapter 23:

Electric Potential

1. (a) What is the electric potential energy of two point charges q and q_0 a distance r apart?

(b) A pair of charged metal plates (the top is negative and the bottom is positive) sets up a uniform electric field with magnitude E. What are the direction and magnitude of the force exerted on a positive charge q placed in that field?

(c) The potential at a certain distance from a point charge is 720 V, and the electric field is 180 NC^{-1}. What is the charge?

(1 mark)

2. (a) The potential difference between two oppositely charged parallel metal plates is 120 V and the distance between them is 3.0 cm. Find the magnitude of the electric field between the plates.

(b) The potential difference between two oppositely charged parallel metal plates is 450 V. Find the work done on a charge of 40 mC as it moves from the higher potential plate to the lower.

(c) When a charge of 20 μC is moved between two points M and N, in a uniform electric field, 240 μJ of work is done. What is the potential difference between M and N?

(1 mark)

3. (a) A positive charge of 4.0 μC is moved through an electric field to a point where the potential is +250 V higher than before. Find the increase in the potential energy of the system.

A proton, of mass 1.67×10^{-27} kg, is released from rest in a uniform electric field of magnitude 7.50×10^{4} V/m directed along the positive x–axis. The proton undergoes a displacement of 0.600 m in the direction of **E**.

(b) What is the change in the electric potential?

(c) Find the change in potential energy of the proton for this displacement.

(d) What is the speed of the proton after it has moved 0.600 m, starting from rest?

(2 marks)

4. A 3.00–μC point charge is located at the origin, and a second point charge of –6.00 μC is located on the y–axis at the position (0, 2.00) m.

(a) Find the total electric potential due to these charges at the point P, whose coordinates are (1.50,0) m.

(b) What is the work required to bring a –3.00–μC point charge from infinity to the point P?

(2 marks)

5. (a) What is the change in potential energy a 16.0–μC charge experiences when it is moved between two points for which the potential difference is 75.0 V?

(b) The gap between the electrodes in a spark plug is 0.0800 cm. To produce an electric spark in a gasoline–air mixture, an electric field of 4.50×10^6 V/m must be achieved. When starting the car, what is the minimum voltage that must be applied by the ignition circuit?

(1 mark)

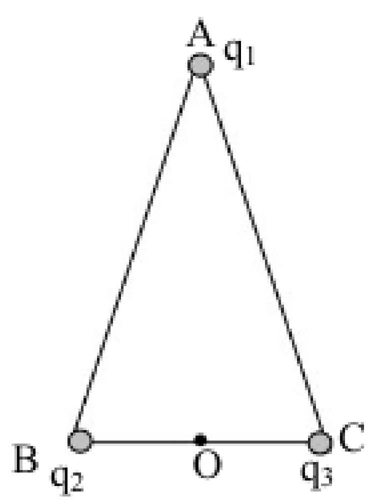
6. What is the speed of a proton, of mass 1.67×10^{-27} kg, that is accelerated from rest through a potential difference of 105 V?

(1 mark)

7. An electron, of mass 9.11×10^{-31} kg, moving parallel to the x–axis has an initial speed of 3.00×10^6 m/s at the origin O. Its speed is reduced to 2.10×10^5 m/s at point A. Find the potential difference V_{AO} of point A relative to the origin O.

(1 mark)

8.



The three charges in the figure are at the vertices of an isosceles triangle ABC, where AB = AC = 5.00 cm, and BC = 4.0 cm. q_1 = +4.00 μC, q_2 = q_3 = –4.00 μC. O is the midpoint of BC.

(a) What is the potential at O due to q_1?

(b) What is the potential at O due to q_2?

(c) Find the total electric potential at O.

(d) A point charge q_0 = 3.00 μC is placed at O. Find the electric potential energy associated with q_o.

(2 marks)

9. Two point charges Q_1 = +7.00 nC and Q_2 = –2.00 nC, are separated by 36.0 cm.

(a) What is the potential energy of the pair?

(b) Find the electric potential at a point midway between the charges.

(1 mark)

Chapter 24:

Capacitance and Dielectrics

1. (a) What is the capacitance of a parallel–plate capacitor? Define all its terms.

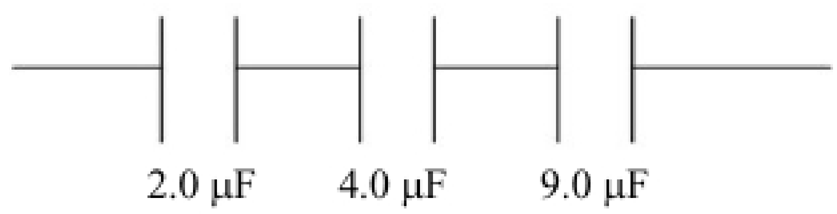
(b) Give the expression of the capacitance C of a parallel–plate capacitor with common plate area A and plates separated by a layer of dielectric constant K and thickness d.

(c) A capacitor acquires a charge of 156 μC when it is connected to a potential difference of 24.0V, find its capacitance.

(1 mark)

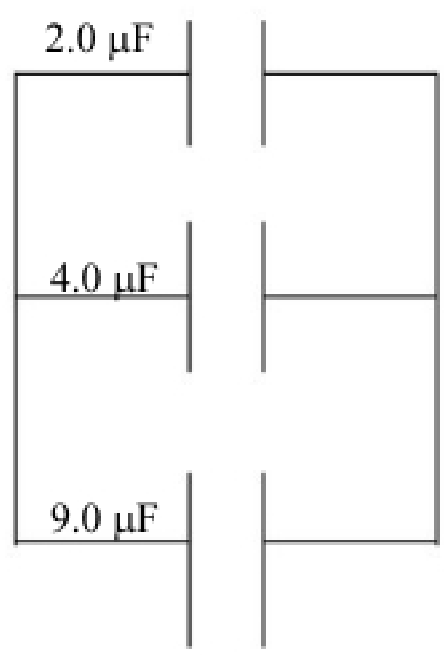
2. (a) The plates of a parallel–plate capacitor in vacuum are 3.54 mm apart and 4.00 m^2 in area. Permittivity of free space = 8.85×10^{-12} F/m. Calculate its capacitance.

(b) Find the equivalent capacitance of the following combination.



(1 mark)

3. (a) Find the equivalent capacitance of the following combination.



(b) A 0.25–μF capacitor is charged so that the potential difference between its plates is 400 V. What is the stored energy?

(1 mark)

4. (a) A capacitor of capacitance 25.0 μF has a charge of 12.5 μC. Find the stored energy.

(b) The potential difference across a capacitor is 60 V and its charge is 3.5 μC. Calculate the stored energy.

(1 mark)

5. A parallel–plate capacitor has plates of dimensions 1.50 cm × 5.00 cm separated by a 1.40–mm thickness of bakelite of relative permittivity 4.90 and dielectric strength 2.40×10^7 V/m. Permittivity of free space 8.85×10^{-12}.

(a) Find the capacitance of the device.

(b) What is the maximum energy that can be stored in the capacitor?

(1 mark)

6. (a) When a potential difference of 175 V is applied to the plates of a parallel–plate capacitor, the plates carry a surface charge density of 35.0 nC/cm^2. What is the spacing between the plates?

A small object with a mass of 300 g carries a charge of 20.0 nC and is suspended by a thread between the vertical plates of a parallel–plate capacitor. The plates are separated by 5.00 cm. The thread makes an angle of 18.0° with the vertical.

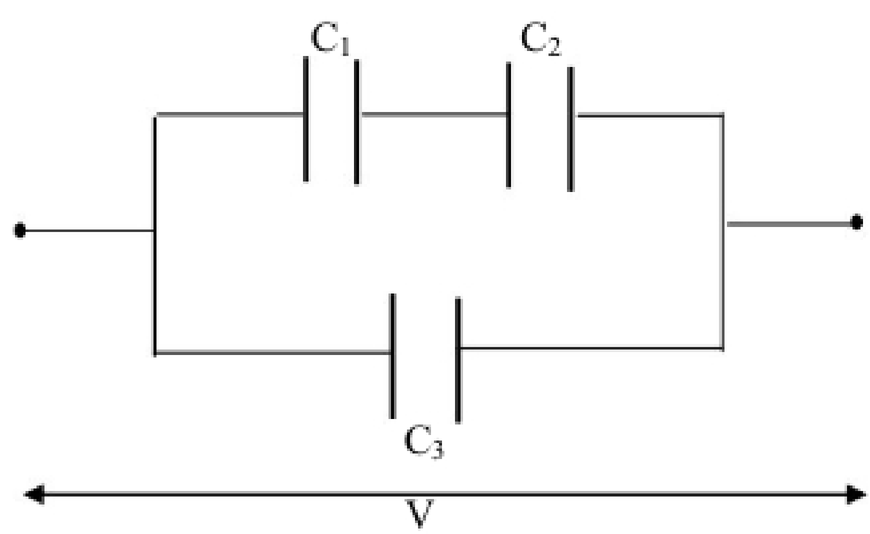
(b) Calculate the tension in the thread.

(c) What is the magnitude of the electric field between the plates?

(d) Find the potential difference between the plates.

(2 marks)

7.



In the capacitor network shown in the figure: $C_1 = 4.00$ μF, $C_2 = 6.00$ μF, $C_3 = 3.60$ μF, V = 15.0V.

(a) Find the equivalent capacitance C_4 of C_1 and C_2.

(b) Find the equivalent capacitance C_{eq} of C_3 and C_4.

(c) What is the potential difference across C_1?

(d) Find the charge on C_3.

(2 marks)

8. A 4.00–μF capacitor and a 16.0–μF capacitor are connected in series across a 50.0–V supply line.

(a) What is the equivalent capacitance?

(b) Find the charge on each capacitor.

The charged capacitors are disconnected from the line and from each other and then reconnected to each other, with terminals of like sign together.

(c) What is the final voltage across each?

(d) Find the final charges on C_1 and C_2 respectively.

(2 marks)

9. The square plates of a 7.50–nF capacitor measure 50.0 mm by 50.0 mm and are separated by a dielectric which is 0.250 mm thick. The voltage rating of the capacitor is 400 V.
Permittivity of free space = 8.85×10^{-12}.

(a) What is the maximum energy that can be stored in the capacitor?

(b) Find the dielectric constant of the dielectric.

(c) Calculate the dielectric strength of the dielectric.

(2 marks)

Chapter 25:

Current, Resistance and E.M.F.

1. (a) A current of 3.20 A flows through a bulb. How many coulombs of charge flow through the bulb in 7.50 h?

(b) A wire of cross–sectional area 1.40 mm^2 has 8.20×10^{27} free electrons per cubic metre. The electrons, each of charge 1.60×10^{-19} C, drift at an average speed of 1.10 mm/s. Find the current in the wire.

(1 mark)

2. (a) A wire of resistivity 9.42×10^{-8} Ωm is 15.0 m long and has a radius of 2.00 mm. What is its resistance?

(b) The resistivity of a certain metal is 2.30×10^{-7} Ωm at 20.0 °C. Its temperature coefficient is 0.00600 $(C°)^{-1}$. Calculate its resistivity at 35.0 °C.

(1 mark)

3. (a) A resistance of 3.20 Ω is connected to the terminals of a cell of e.m.f. 10.8 V and internal resistance 0.400 Ω. What is the p.d across the 3.20–Ω resistor?

(b) A cell of e.m.f. 12.0 V and internal resistance 1.50 Ω is connected across a 2.50–Ω resistor. Find the charge which passes any point in the circuit in three minutes.

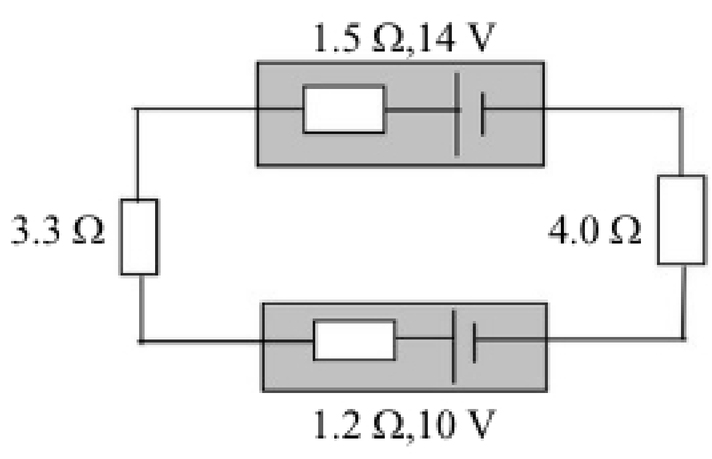
(1 mark)

4. (a) The resistance of a certain length of copper wire is 3.00 Ω at 20.0 °C. If the temperature coefficient of copper is 4.00×10^{-3} K^{-1}, what is its resistance at 65.0 °C?

(b) A cell of e.m.f. 6.4 V and internal resistance 0.10 Ω is connected across a 1.5–Ω resistor. Find the net output of the battery.

(1 mark)

5.



(a) Calculate the current in the circuit.

(b) Find the total rate of dissipation of energy.

(c) Find the rate of conversion of electrical energy to chemical energy.

(d) Find the rate of conversion of chemical energy to electrical energy.

(2 marks)

6. A resistance thermometer, which measures temperature by measuring the change in resistance of a conductor, is made from silver, of temperature coefficient of resistivity 3.80×10^{-3} $(°C)^{-1}$, and has a resistance of 40.0 Ω at 31.0 °C. When immersed in a vessel containing melting lead, its resistance increases to 85.0 Ω. Calculate the melting point of lead.

(1 mark)

7. (a) An electric heater is constructed by applying a potential difference of 150 V to a Nichrome wire of total resistance 10.0 Ω. Find the power rating of the heater, in kW.

(b) A 20.0–Ω metal wire is cut into four pieces that are then connected side by side to form a new wire the length of which is equal to one–fourth the original wire. What is the resistance of this new wire?

(1 mark)

8. (a) A 2.10–V potential difference is maintained across a 2.00–m length of tungsten wire of resistivity 5.60×10^{-8} Ωm, that has a cross–sectional area of 0.500 mm^2. Find the current in the wire.

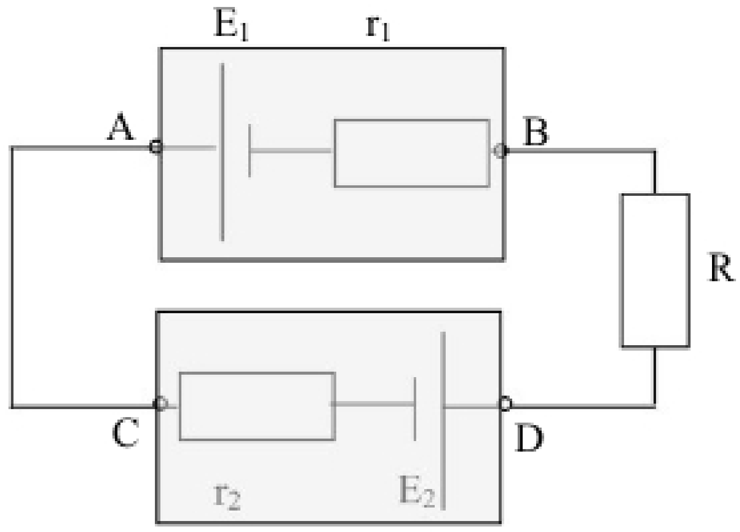
(b) A segment of Aluminum wire of temperature coefficient of resistivity 3.90×10^{-3} $(°C)^{-1}$ is initially at 21.0 °C. To which temperature must the wire be heated to quadruple its resistance?

(1 mark)

9. A wire with resistance 6.00 Ω is lengthened 1.50 times its original length by pulling it through a small hole. Find the resistance of the wire after it is stretched.

(1 mark)

10.



In the above circuit: $E_1 = 14.0$ V, $r_1 = 3.00\ \Omega$, $E_2 = 10.0$ V, $r_2 = 2.00\ \Omega$, $R = 5.00\ \Omega$.

(a) What is the current?

(b) Find the potential V_{AB} of point A relative to point B.

(c) Find the potential V_{DC} of point D relative to point C.

(d) What is the total rate of dissipation of energy in the circuit?

(2 marks)

Chapter 26

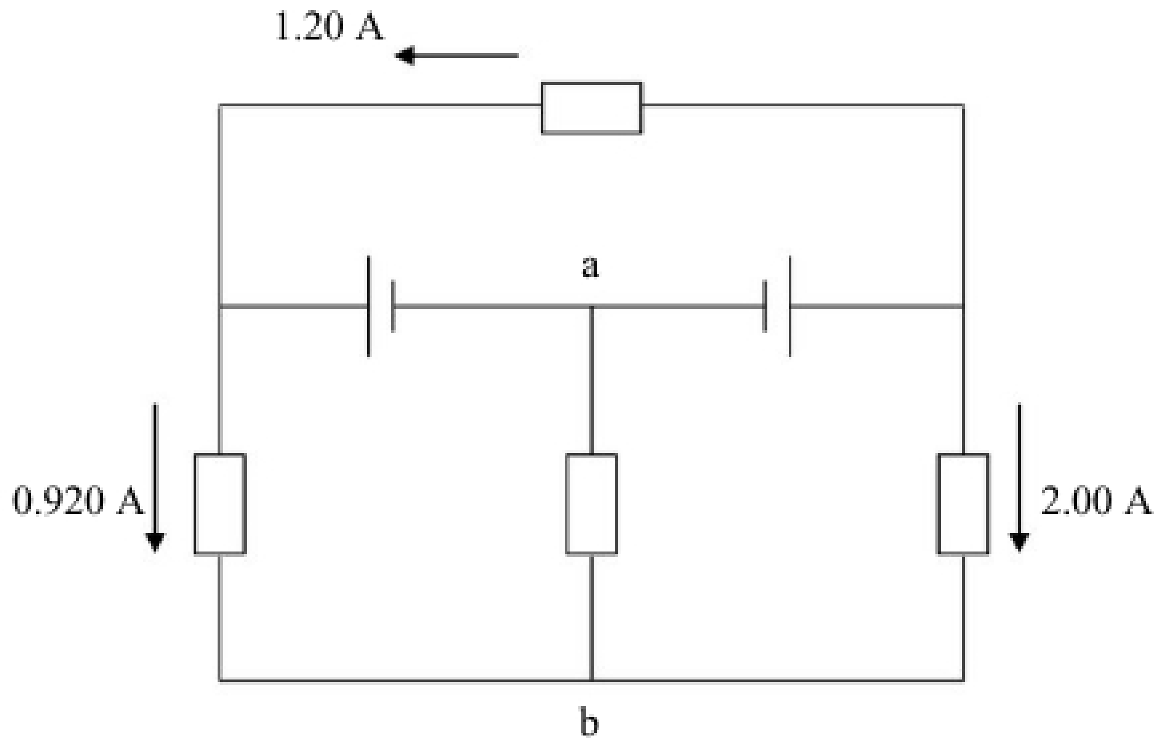
Direct – Current Circuits

1. (a) Three resistors of resistances $R_1 = 1.00\ \Omega$, $R_2 = 3.00\ \Omega$ and $R_3 = 5.00\ \Omega$ are connected in series. Find their equivalent resistance.

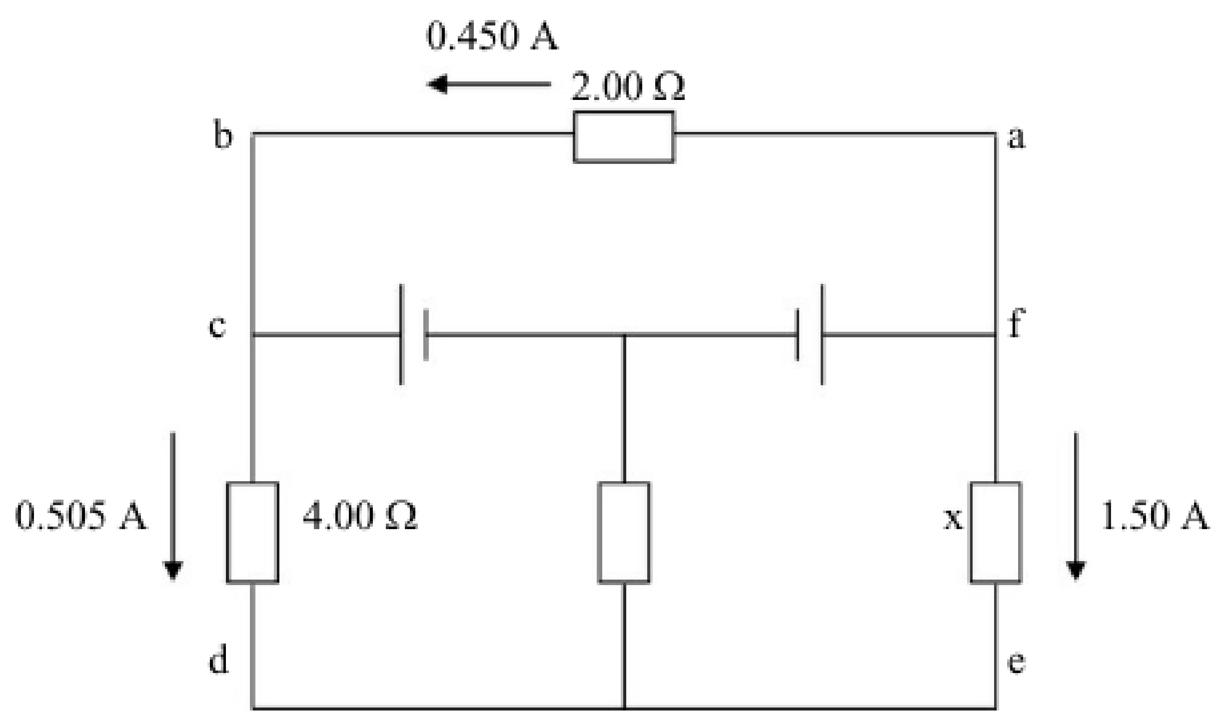
(b) Three resistors of resistances $R_1 = 1.00\ \Omega$, $R_2 = 3.00\ \Omega$ and $R_3 = 5.00\ \Omega$ are connected in parallel. Find their equivalent resistance.

(1 mark)

2. (a) What is the current from a to b?



(b) Applying Kirchhoff's loop rule for the loop abcdefa, find the resistance x.



(1 mark)

3. (a) A galvanometer has coil resistance R_C and f.s.d. current I_{fs}. If it is to be converted to an ammeter of f.s.d. current I_a, what is the shunt resistance required?

(b) A galvanometer has coil resistance R_C and f.s.d. current I_{fs}. If it is to be converted to a voltmeter of f.s.d. V_V, find the resistance required.

(1 mark)

4. (a) An ammeter of 48.5 Ω resistance gives a full scale deflection for 3.0 mA. What must the meter have added to it to give a full scale deflection for 100 mA?

(b) A galvanometer of coil resistance 20.0 Ω and f.s.d. current 2.00 mA is to be converted to a voltmeter with a maximum range of 16.0 V. What is the series resistance to be used?

(1 mark)

5. (a) In the R–C circuits, give the formulae of current and charge in terms of time:
(i) while charging
(ii) while discharging

A resistor with resistance 12.0 MΩ is connected in series with a capacitor with capacitance 2.00 μF and a battery with e.m.f. 12.0 V. Before the switch is closed at t = 0, the capacitor is uncharged.

(b) Find the time constant.

(c) What is the current at t=0 when the switch is closed?

(d) Find the final charge on the capacitor.

(1 mark)

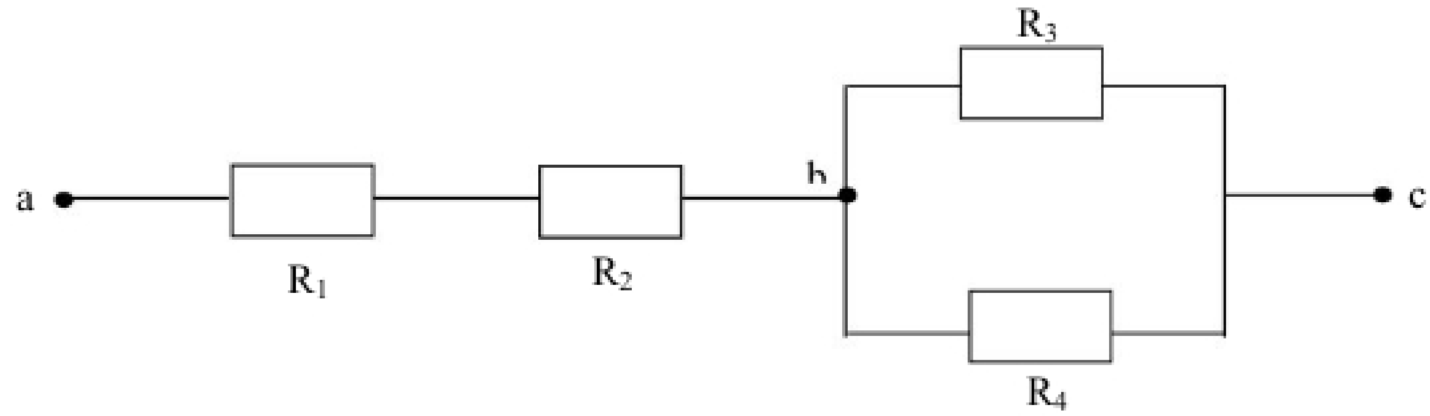
6. A resistor with resistance 12.0 MΩ is connected in series with a capacitor with capacitance 2.00 μF and a battery with e.m.f. 12.0 V. Before the switch is closed at t = 0, the capacitor is uncharged.

(a) Calculate the current at one time constant.

(b) Calculate the charge at one time constant.

(1 mark)

7.



Four resistors are connected as shown. $R_1 = 3.00\ \Omega$, $R_2 = 4.00\ \Omega$, $R_3 = 24.0\ \Omega$, $R_4 = 12.0\Omega$. $V_{ac} = 22.5$ V

(a) What is the equivalent resistance between a and c?

(b) Find the current through R_3.

(1 mark)

8. (a) The currrent in a loop circuit that has a resistance R_1 is 4.0 A. The current is reduced to 3.0 A when an additional resistor $R_2 = 2.5\ \Omega$ is added in series with R_1. What is the value of R_1?

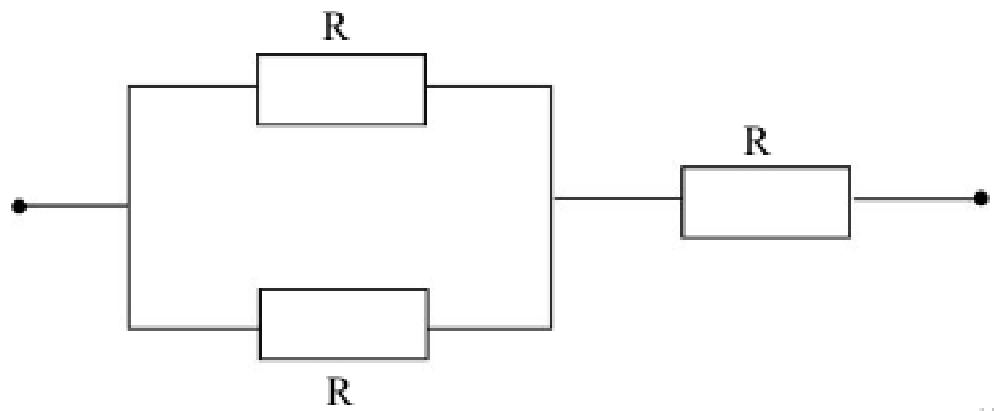
(b) A battery with an e.m.f. of 15.0 V and internal resistance of 0.800 Ω is connected across a load resistor R. If the current in the circuit is 2.50 A, find the power dissipated in R.

(1 mark)

9. The current in a circuit is quadrupled by connecting a 600–Ω resistor in parallel with the resistance R of the circuit. Calculate the resistance R.

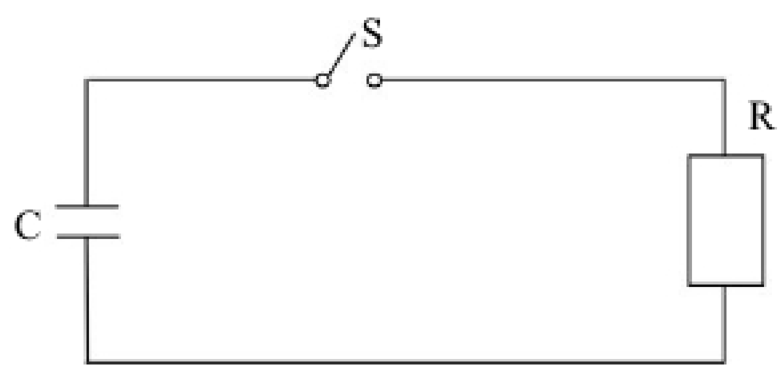
(1 mark)

10. Three resistors each having resistance R = 3.0 Ω are connected as in the figure. Each can dissipate a maximum power of 48 W without being excessively heated. Find the maximum power the network can dissipate.



(1 mark)

11. Initially, for the circuit shown, the switch S is open and the capacitor, of capacitance 20.0 μF, has a voltage of 120 V, and R = 3.00 MΩ. The switch is closed at time $t = 0$.



(a) Calculate the charge on the capacitor, when the current in the circuit is 35.0 μA.

(b) Find the capacitor voltage when the time is equal to 75.0 s.

(1 mark)

Chapter 27:

Magnetic Field and Magnetic Forces

1. (a) An electron of charge 1.6×10^{-19} C moves with a speed of 4.0×10^{6} m/s along the x axis. It enters a region where there is a magnetic field of magnitude 1.5 T, directed at an angle of 30° to the x–axis and lying in the xy plane. Find the magnitude and direction of the magnetic force on the electron.

(b) A disc of radius 1.5 cm is found in a region of uniform magnetic field of 4.0 T making an angle of 37° with the plane of the disc. Calculate the magnetic flux through the disc.

(1 mark)

2. (a) A proton of mass 1.67×10^{-27} kg and charge 1.60×10^{-19} C moving with a speed of 2.50×10^{5} m/s enters a region of uniform magnetic field perpendicular to its direction of motion and of magnitude 0.800 T. Find the radius of its trajectory.

(b) In a velocity selector of crossed electric and magnetic fields, the magnitude of the electric field is 5.0×10^{6} V/m and that of the magnetic field is 0.80 T. What is the speed of the particle?

(1 mark)

3. (a) A wire carries a steady current of 2.5 A. A straight section of the wire is 0.60 m long and lies along the x axis within a uniform magnetic field, **B** = (2.4 T) **k**. If the current is in the + × direction, find the magnetic force on the section of the wire.

(b) A circular coil 6.0 cm in radius, with 60 turns of wire, carries a current of 5.0 A. The coil is in a uniform magnetic field with magnitude 4.0 T making an angle of 60° with the plane of the coil. Find the torque on the coil.

(1 mark)

4. (a) The Earth's magnetic field at a certain place is 3.2×10^{-5} T at an angle of 30° with the horizontal. Calculate the flux through the horizontal ceiling of a rectangular room 6.0 m by 8.0 m.

(b) A particle with a charge of -6.0×10^{-8} C is moving with instantaneous velocity of $(4.5 \times 10^{4} m/s)\ \hat{j}$. Find the force exerted on the particle by a magnetic field $(5.0T)\ \hat{k}$.

(1 mark)

5. (a) An electron experiences a magnetic force of magnitude 6.7×10^{-15} N when moving at an angle of 37° with respect to a magnetic field of magnitude 3.5×10^{-3} T. What is the speed of the electron?

(b) A circular area with a radius of 5.0 cm lies in the xy plane. Find the magnitude of the magnetic flux through this circle due to a uniform magnetic field of magnitude 0.60 T in the +z direction.

(1 mark)

6. (a) A singly charged ion moving with a speed of 3.9×10^5 m/s enters a region of uniform magnetic field of magnitude 0.52 T, perpendicular to the direction of motion of the ion, and describes a circular arc of radius 50 cm. What is the mass of the ion?

(b) A horizontal rod 35 cm long is mounted on a balance and carries a current. At the location of the rod a uniform horizontal magnetic field has magnitude 0.020 T and direction perpendicular to the rod. The magnetic force on the rod is measured by the balance and is found to be 0.21 N. Find the current.

(1 mark)

7. A wire having a mass per unit length of 0.600 g/cm carries a 3.00–A current horizontally to the north. What are the magnitude and direction of the minimum magnetic field needed to lift this wire vertically upward?

(1 mark)

8. Alpha particles (charge =+2e, mass = 6.68×10^{-27} kg) are accelerated in a cyclotron to a final orbit radius of 0.800 m. The magnetic field in the cyclotron is 0.600 T.

(a) Find the period of circular motion of the alpha particles.

(b) What is the magnitude of the centripetal acceleration of the alpha particles in the final orbit?

(2 marks)

9. A uniform magnetic field of magnitude 0.60 T in the positive z–direction is present in a region of space. A uniform electric field is also present. An electron projected with an initial velocity v_0 = 2.5 x 10^4 m/s in the positive x–direction, traverses the region without deflection. What is the electric field vector?

(1 mark)

10. A 12–m length of wire carrying a current of 5.6 A lies on a horizontal table with a rectangular top of dimensions 180 x 240 cm^2. The ends of the wire are attached to opposite ends of a diagonal of the rectangle. A vertical magnetic field of 0.25 T is present. Find the magnitude of the magnetic force acting on this segment of wire.

(1 mark)

11. (a) A circular coil of wire of 250 turns and diameter 2.50 cm carries a current of 4.50 A. It is placed in a magnetic field of 0.400 T with the plane of the coil making an angle of 37.0° with the magnetic field. Find the torque on the coil.

(b) A particle of charge –5.00 μC and mass 3.50×10^{-12} kg has velocity 4.00 km/s as it enters a region of uniform magnetic field. The particle is observed to travel in a circular path of radius 7.50 cm. What is the magnitude of the magnetic field in the region?

(1 mark)

Chapter 28:

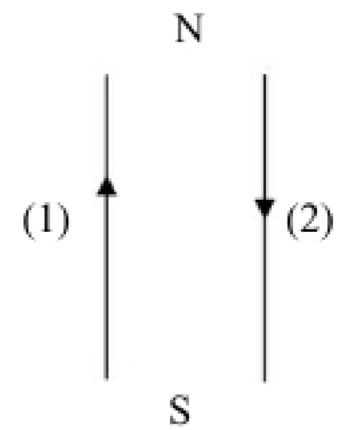
Sources of magnetic Field

1. (a) What is the constant current flowing in a straight wire required to give a magnetic field of 2.0×10^{-5} T at 2.5 cm from the wire?

(b) A circular coil of radius 4.0 cm and 200 turns lies in the plane of this paper and carries a current of 2.5 A in an anticlockwise sense. Determine the field at the centre of the coil.

(1 mark)

2.



(a) Two long parallel conductors run North–South in the same horizontal plane as shown in the diagram. (1) carries a current 20 A northward and (2) a current 20 A southward, and they are 5.0 cm apart. Determine the force per unit length of (2) on (1).

(b) A solenoid with 800 turns, 75 cm long and 6.0 cm in diameter, lies with its axis North–South and carries a current of 6.0 A in a clockwise sense when viewed from the South end. Find the magnitude and direction of the field at the centre of the solenoid.

(1 mark)

3. (a) What is the magnitude of the magnetic field produced by a straight long wire carrying a current of 45 A at 18 cm from the wire?

(b) Two long, parallel wires are separated by a distance of 3.5 cm. The force per unit length that each wire exerts on the other is 6.0×10^{-5} N/m, and the wires attract each other. If the current in one wire is 2.1 A, find the current in the second wire.

(1 mark)

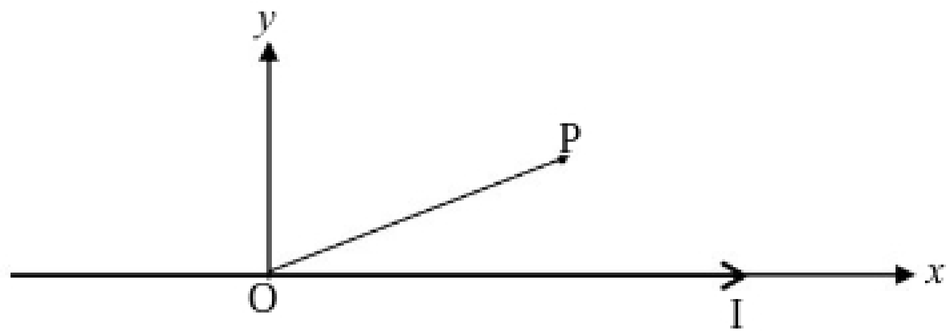
4. (a) A closely wound circular coil with 600 turns carries a current of 2.5 A and produces at its centre a magnetic field of magnitude 3.8×10^{-3} T. What is its diameter?

(b) A solenoid is designed to produce a magnetic field of 0.06030 T at its centre and it carries a current of 16.00 A. Find the number of turns per unit length?

(1 mark)

5.

(a)

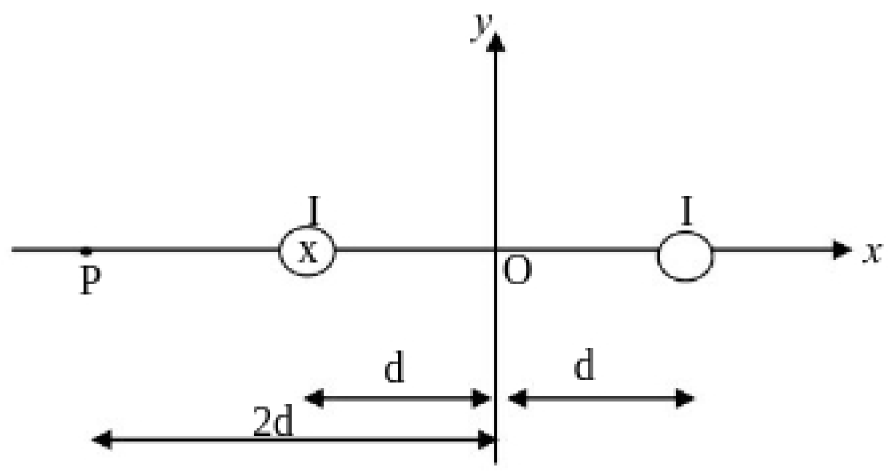


A long, straight conductor lies along the x–axis and carries a current of 200 A in the positive x–direction. Determine the magnetic field at point P in the diagram, such that OP = 1.50 m and = 40.0 :

(b) Give the official SI definition of the ampere.

(1 mar k)

6.



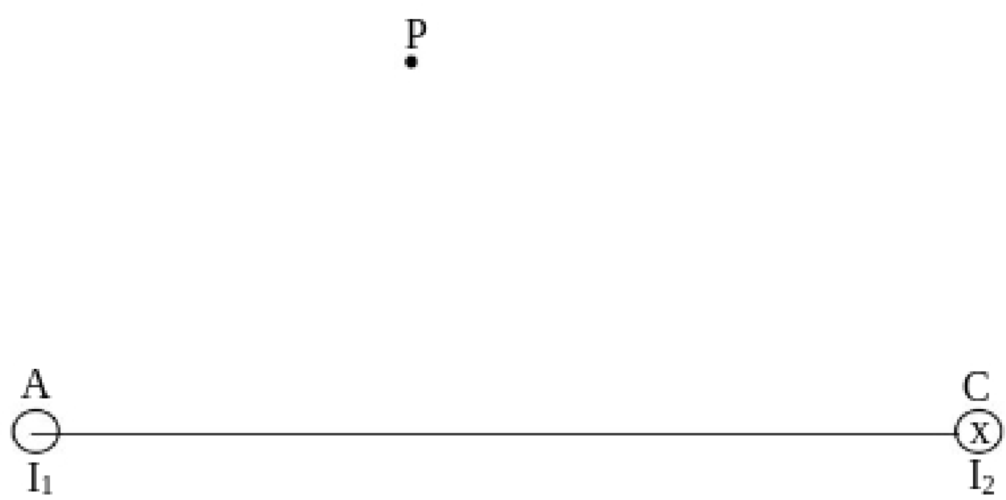
The figure is an end view of two, long, straight, parallel wires perpendicular to the xy–plane, each carrying a current I = 7.00 A but in opposite directions. d = 8.00 cm.

(a) Find the magnetic field at O.

(b) Find the magnetic field at P.

(2 mark s)

7.



Two long, straight, parallel wires are 4.00 m apart. They carry currents in opposite direction, as shown in the figure. I_1 = 9.00 A, I_2 = 16.0 A, AP = 2.40 m, CP = 3.20 m.

(a) What is the magnetic field $\mathbf{B_1}$ at P due to I_1?

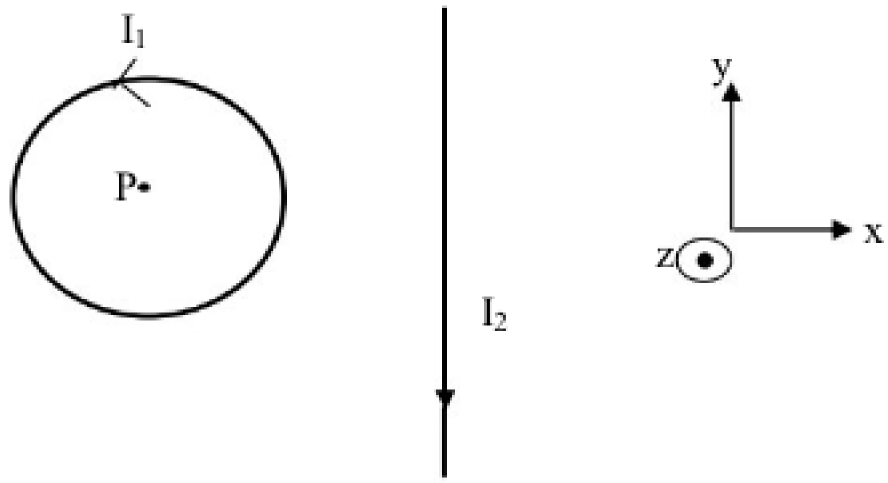
(b) What is the magnetic field $\mathbf{B_2}$ at P due to I_2?

(c) Find the magnitude of the resultant magnetic field at P.

(d) Find the acute angle the resultant magnetic field at P makes with the direction AP.

(2 marks)

8.



A coil consisting of 40.0 turns has a radius of 12.6 cm and carries a current $I_1 = 4.00$ A as shown in the figure. A long, straight conductor, which is in the plane of the coil, carries a current $I_2 = 350$ A at a distance of 17.5 cm from the centre P of the coil.

(a) What is the magnetic field $\mathbf{B_1}$ at P due to I_1?

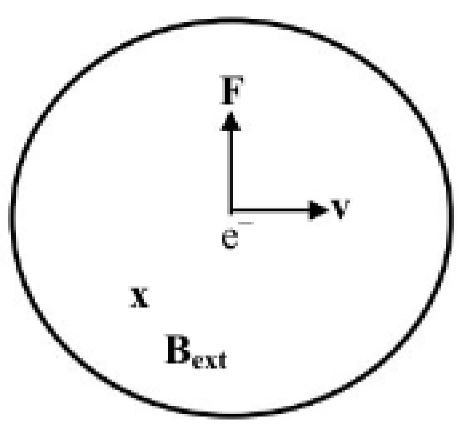
(b) What is the magnetic field $\mathbf{B_2}$ at P due to I_2?

(c) Find the net magnetic field at P.

(d) If the current I_2 were 350 A in the positive *y* direction, what would the net field at P be?

(2 marks)

9.



A conducting ring of radius 6.28 cm carries a current of unknown magnitude and sense. A uniform external magnetic field B_{ext} = 150 μT, directed into the plane, is applied as shown in the figure. An electron is projected from the centre of the ring, with an initial velocity 4.00×10^5 m/s towards the right. The electron experiences an initial force 1.60×10^{-17} N in the upward direction.

(a) What is the magnitude of the net magnetic field?

(b) Deduce the magnitude of the magnetic field produced by the current at the centre of the ring.

(c) Find the current in the ring.

(2 marks)

Relativity

1. (a) Define an inertial frame of reference·

   (b) State Einstein’s first postulate·

   (c) State Einstein’s second postulate·

   (d) Give the Galilean transformations·

(1 mark)

2. An unstable particle lives on average about 2.8 10^{-8} s (measured in its own frame of reference) before decaying. If such a particle is moving with respect to the laboratory with a speed of 0.70c, calculate its lifetime measured in the laboratory.

(1 mark)

3. You are on earth as a spaceship flies past at a speed u relative to the earth. A high–intensity signal light on the ship blinks on and off, each pulse lasts 3.00 10^{-6} s as measured on the spaceship. If you measure 1.30 10^{-5} s for the duration of each light pulse, what is the value of u?

(1 mark)

4. In the year 2010 a spacecraft flies over moon station III at a speed of 0.700c. A scientist on the moon measures the length of the moving spacecraft to be 250m. The spacecraft later lands on the moon, and the same scientist measures the length of the now stationary spacecraft. What value does she get?

(1 mark)

5. A meter stick moves past you at great speed. If you measure the length of the moving meter stick to be 0.90 m, then with what speed is the meter stick moving relative to you?

(1 mark)

6. Two particles emerge from a high–energy accelerator in opposite directions, each with a speed 0.90c as measured in the laboratory. Find the magnitude of the relative velocity of the particles.

(1 mark)

7. A spaceship moving away from the earth with speed 0.60c fires a space probe in the same direction as its motion, with speed 0.70c relative to the spaceship. What is the probe’s speed relative to the earth?

(1 mark)

8. How fast must you be approaching a red traffic light of wavelength 700 nm for it to appear violet of wavelength 400 nm?

(1 mar k)

9. At what speed is the relativistic momentum of a particle four times as great as the Newtonian momentum?

(1 mark)

10. At what speed does the relativistic momentum of a particle differ by 2.00 per cent from the Newtonian value?

(1 mark)

11. A force F is required to give a 0.180–kg baseball an acceleration $a = 1.50\ ms^{-2}$ in the direction of the baseball's initial velocity when this velocity has a magnitude of 0.700c. Find the magnitude of F.

(1 mark)

12. Find the work that must be done to accelerate a particle of mass m from rest to a speed of 0.25c.

(1 mark)

13. In an annihilation process, two particles collide and disappear, producing electromagnetic radiation. If each particle has a mass of 7.5 10^{-31} kg and they are at rest just before annihilation, calculate the total energy of the radiation.

(1 mark)

14. An electron of mass 9.11 10^{-31} kg in a certain x–ray tube is accelerated from rest through a potential difference of 2.40 10^{5} V going from the cathode to the anode. When it arrives at the anode, what is its total energy in MeV?

(1 mark)

15. At what speed is the kinetic energy of a particle three times its rest energy?

(1 mark)

<u>Use the following information to answer questions 16 and 17:</u>

Two frames F and F' are at the same position when the two frames show time = 0. F' is moving to the right with a constant speed of 0.70c along the x–axis. An event takes place at $x = 4.5$ 10^{8} m and $t = 2.0$ s as measured by F.

16. Find the x coordinate of the event as measured by F'.

(1 mark)

17. Find the time of the event as measured by F'.

(1 mark)

Mechanics

Part 1

1. (a) A string has a natural length 180 cm and a modulus 15.0 N. Find its length when the tension is 8.00 N.

(b) A spring is clamped at one end and its length is measured when two different masses are hung from the other end. When 200 g is hung, the length is 43.5 cm and when 280 g is hung, the length is 44.9 cm. Find the modulus of the spring.

(c) A spring has a stiffness of 400.0 N/m and has a length of 27.45 cm when a mass of 1.000 kg is hung from one end. Find its modulus of elasticity.

[part 1–page 5]
(2 marks)

2. (a) A light elastic string of natural length 50.0 cm and modulus 40.0 N has one end fixed. A particle of mass 2.00 kg is attached to the other end and hangs in equilibrium. Calculate the extended length of the string.

(b) A rope is tied to a branch of a tree. When the rope is hanging freely in equilibrium its length is 2.50 m. When a child of mass 40.0 kg hangs in equilibrium from the end of the rope, the length of the rope is 2.70 m. Choose suitable models for the rope and the child and hence calculate the modulus of the rope.

[part 1–page 5]
(1 mark)

3. (a) An elastic string has natural length 2.00 m and modulus 30.0 N. Find the tension in the string when the extension is 0.500 m.

(b) An elastic string has modulus 25.0 N and the tension in the string is 40.0 N. Find the natural length if the extension is 10.0 cm.

[part 1–page 5]
(1 mark)

4. (a) The tension in an elastic string of modulus 30.0 N is 50.0 N. The length of the string is 1.50 m. Calculate the natural length of the string.

(b) A spring of modulus 40.0 N and natural length 0.500 m is compressed to a length of 0.400 m. Calculate the thrust produced.

[part 1–page 5]
(1 mark)

5. (a) A spring of natural length 1.00 m exerts a thrust of 45.0 N when compressed to a length of 0.750 m. Calculate the modulus of the spring.

(b) A force of 5.00 N is applied to an elastic string of natural length 2.50 m and modulus 4.00 N. Calculate the extension produced.

[part 1–page 5]
(1 mark)

6. (a) An elastic spring of modulus 50.0 N has one end fixed. When a particle of mass 2.00 kg is hanging in equilibrium attached to the free end of the spring, the spring is extended by 5.00 cm. Find the natural length of the spring.

(b) A particle of mass 6.00 kg hangs vertically from the free end A of an elastic string AB. End B of the string is fixed. If the extension in the string is equal to its natural length, determine the modulus of the string.

[part 1–page 5]
(1 mark)

7. An elastic string of modulus 20.0 N has one end fixed. When a particle of mass 1.00 kg is hanging in equilibrium from the free end of the string, the length of the string is 1.40 m.

(a) Determine the natural length of the string.

(b) The particle of mass 1.00 kg is removed and replaced by a particle of mass 0.750 kg. Calculate the new length of the string.

[part 1–page 5]
(1 mark)

8. A particle of mass 4.00 kg is attached to one end A of a light elastic string AB of modulus 20.0 N and natural length 0.800 m. The end B of the string is attached to a point on a smooth plane inclined at an angle arcsin 5/13 to the horizontal. The particle rests in equilibrium on the plane with AB along a line of greatest slope.
Calculate:

(a) the tension in the string.

(b) the extension of the string.

[part 1–page 5]
(1 mark)

9. An elastic spring is fixed at one end. When a force of 4.00 N is applied to the other end the spring extends by 0.200 m. If the spring hangs vertically supporting a mass of 1.00 kg at the free end, the spring is of length 2.49 m. Find:

(a) the natural length of the spring

(b) the modulus of elasticity of the spring.

[part 1–page 5]
(1 mark)

10. (a) A string will break if the tension in it exceeds 10.0 N. If the maximum extension it can be given is ¼ of its natural length, find its modulus of elasticity.

(b) A force of 2.00 N is applied to an elastic string of natural length 3.00 m so as to stretch it. To what length will the string extend if its modulus of elasticity is 4.00 N?

[part 1–page 5]
(1 mark)

11. A spring of unstretched length l_0 and modulus λ hangs with a scale pan of mass m at its free end. If a mass M is placed gently on the scale pan find how far the new equilibrium position is below the old one.

[part 1–page 5]
(1 mark)

Mechanics

Part 2

1. One end of a string of natural length 1.50 m and modulus 15.0 N is attached to a mass of 12.0 g, the other end being held fixed. The mass executes uniform circular motion at a rate of 5.00 rad/s. Find the radius of the trajectory.

[part 2–page 9]
(1 mark)

2. A particle of mass 3.00 kg is attached by a light inextensible string of length 1.00 m to a fixed point O. The particle is made to move in a horizontal circle whose centre is 0.600 m verttically below O. Find :

(a) the tension in the string.

(b) the speed of the particle.

[part 2–page 10]
(1 mark)

3. A particle P, of mass 800 g, is connected to a light inextensible string of length 60.0 cm. The other end of the string is tied to a fixed point O on a smooth horizontal plane. P moves on the plane in a horizontal circle, centre O, with uniform speed at a frequency of 36.0 revolutions per minute. Find the tension in the string.

[part 2–page 8]
(1 mark)

4. A particle P of mass 500 g rests on a rough horizontal disc at a distance 10.0 cm from the centre. The disc is rotating about its centre. The coefficient of friction between the particle and the disc is 0.250. Given that the particle is on the point of slipping, find the angular speed of the disc.

[part 2–page 8]
(1 mark)

5. (a) A particle P of mass 500 g is attached to one end of a light inextensible string of length 25.0 cm. The other end of the string is fixed to a point O on a smooth horizontal table. P moves with a speed 2.00 m/s in a horizontal circle on the table. Calculate the tension in the string.

(b) A particle P of mass 250 g is attached to one end of a light elastic string of modulus 5.00 N and natural length 75.0 cm. The other end of the string is fixed to a point O on a smooth horizontal table. P moves in a horizontal circle of radius 100 cm. Calculate the constant speed of P.

[part 2–page 8]
(1 mark)

6. (a) A particle P of mass 200 g is attached to one end of a light inextensible string of length 50.0 cm. The other end of the string is fixed to a point O of a smooth horizontal table. P describes horizontal circles, centre O, on the table. Given that the tension in the string is 2.50 N, calculate the speed of the particle.

(b) A smooth wooden hoop of radius 100 cm rests on a smooth horizontal surface. A bead of mass 200 g is moving in a horizontal circle in contact with the inner surface of the hoop. The bead maintains a constant speed of 6.00 m/s. Calculate the magnitude of the reaction between the hoop and the bead.

[part 2–page 8]
(1 mark)

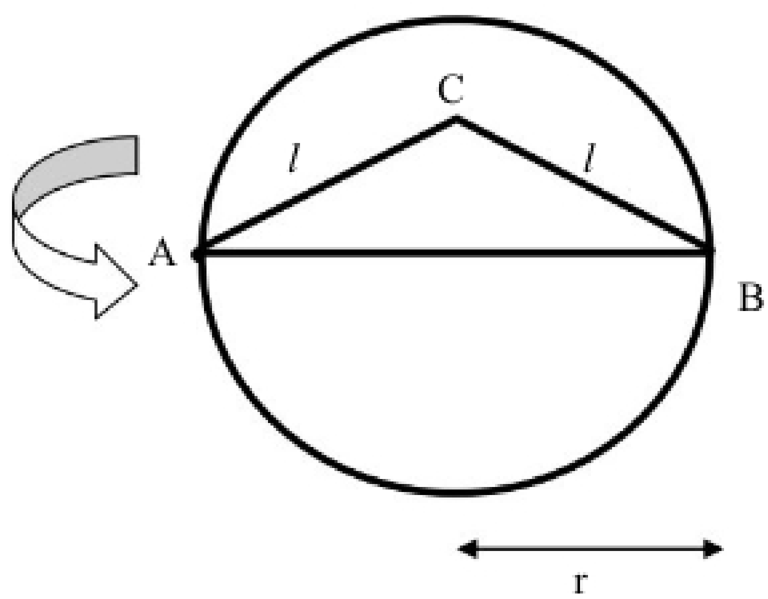
7. A particle P of mass 500 g rests on a rough horizontal disc at a distance of 25.0 cm from the centre. When the disc is rotating with angular speed 5.00 rad/s P is on the point of slipping. Calculate the value of the coefficient of fricion between P and the disc.

[part 2–page 8]
(1 mark)

8. A particle P of mass 200 g is attached to one end of a light elastic string of modulus 20.0 N and natural length 50.0 cm. The other end of the string is fixed to a point O on a smooth horizontal surface. P moves in a horizontal circle with centre O. Given that the speed of P is 10.0 m/s, calculate the radius of the circle.

[part 2–page 8]
(1mark)

9.



A particle of mass 200 g is attached to the end C of two light inextensible strings AC and BC both of length l = 100 cm. The other ends A and B are attached to opposite ends of a diameter of a smooth disc of radius r = 80.0 cm which is free to rotate in a horizontal plane about its centre. The disc rotates with angular speed 10.0 rad/s and P remains in contact with the disc. Calculate the tension in each string.

[part 2–page 8]
(1 mark)

10. A particle of mass m is attached to one end of a light elastic string of natural length l_0 and modulus 5 mg. The other end of the string is fixed to a point O on a smooth horizontal table. The particle moves on the table in a circular path of radius $\frac{6l_0}{5}$ and centre O. Find the constant speed of the particle.

[part 2–page 8]
(1 mark)

11. OB is a light rigid rod of length $5l$. Particles of masses 3 m and 4 m are attached at points A and B of the rod, where OA is $2l$. The rod is made to rotate about O in a horizontal plane with constant angular speed ω.

(a) Find the magnitude of the centripetal force $\mathbf{F_B}$ acting on the particle at B.

(b) Find the magnitude of the tension $\mathbf{F_A}$ in OA.

(c) Calculate the ratio of the magnitudes of the tensions in OA and AB.

[part 2–page 8]
(2 marks)

Mechanics

Part 3

(sections 3.1 till 3.4)

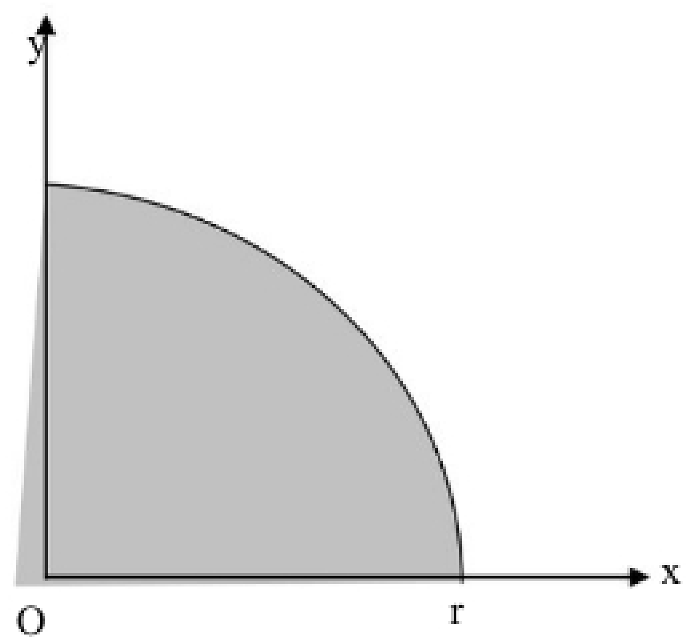
1. A uniform lamina is bounded by the curve with equation $y^2 = 4x$, the x–axis and the line $x = 1$.

(a) Find the x–coordinate of the centre of mass of the lamina.

(b) Find the y–coordinate of the centre of mass of the lamina.

[part 3–page 22]
(2 marks)

2.



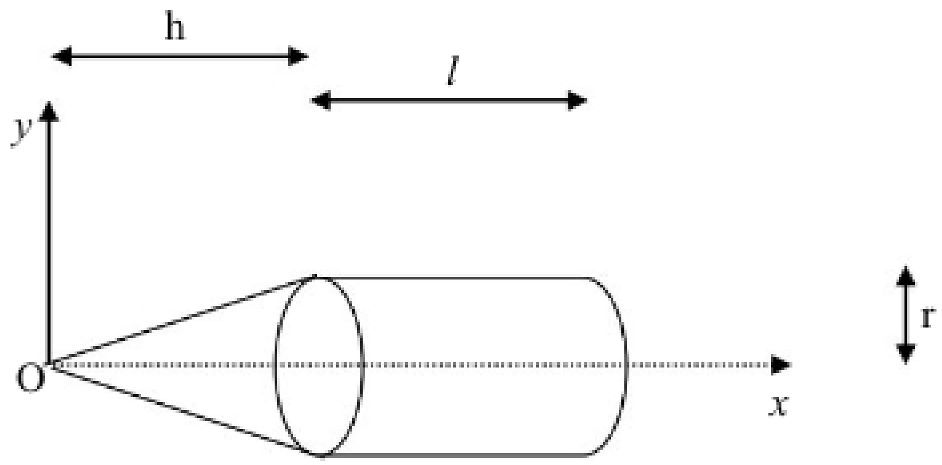
Find the coordinates of the centre of mass of a uniform lamina in the shape of a quadrant of a circle of radius r shown in the figure.

[part 3–page 22]
(2 marks)

3. Find the coordinates of the centre of mass of the solid formed when the finite region bounded by the curve with equation $y = x^2$, the line $x = 1$ and the x–axis is rotated completely about the x–axis.

[part 3–page 23]
(1 mark)

4.



A uniform cone has base radius r = 3.00 cm and height h = 8.00 cm. It is joined to a uniform solid right circular cylinder, of the same density, with the same radius and same height *l* = h, so that the plane base of the cone coincides with a plane face of the cylinder, as shown in the diagram.

(a) Find the coordinates of the centre of mass of the cone.

[part 3–page 18]

(b) Find the coordinates of the centre of mass of the cylinder.

[part 3–page 14]

(c) Find the mass, in terms of ρ and π, of the cone.

[part 3–page 18]

(d) Find the mass, in terms of ρ and π, of the cylinder.

[part 3–page 14]

(e) Give the expression of the coordinates of the centre of mass of a composite body.

[part 3–page 21]

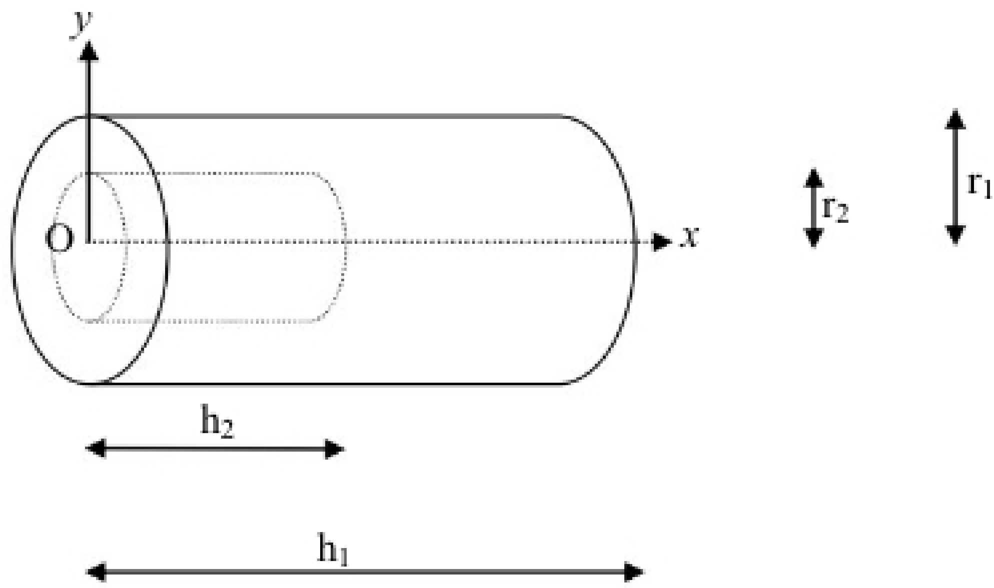
(f) Find the y–coordinate of the centre of mass of the composite body (cone and cylinder).

[part 3–page 14]

(g) Find the x–coordinate of the centre of mass of the composite body (cone and cylinder).

[part 3–page 21]
(2 marks)

5.



A uniform solid cylinder is of radius $r_1 = 4.00$ cm and height $h_1 = 6.00$ cm. A cylindrical hole of radius $r_2 = 2.00$ cm and depth $h_2 = 3.00$ cm is bored centrally at one end O, as shown in the diagram.

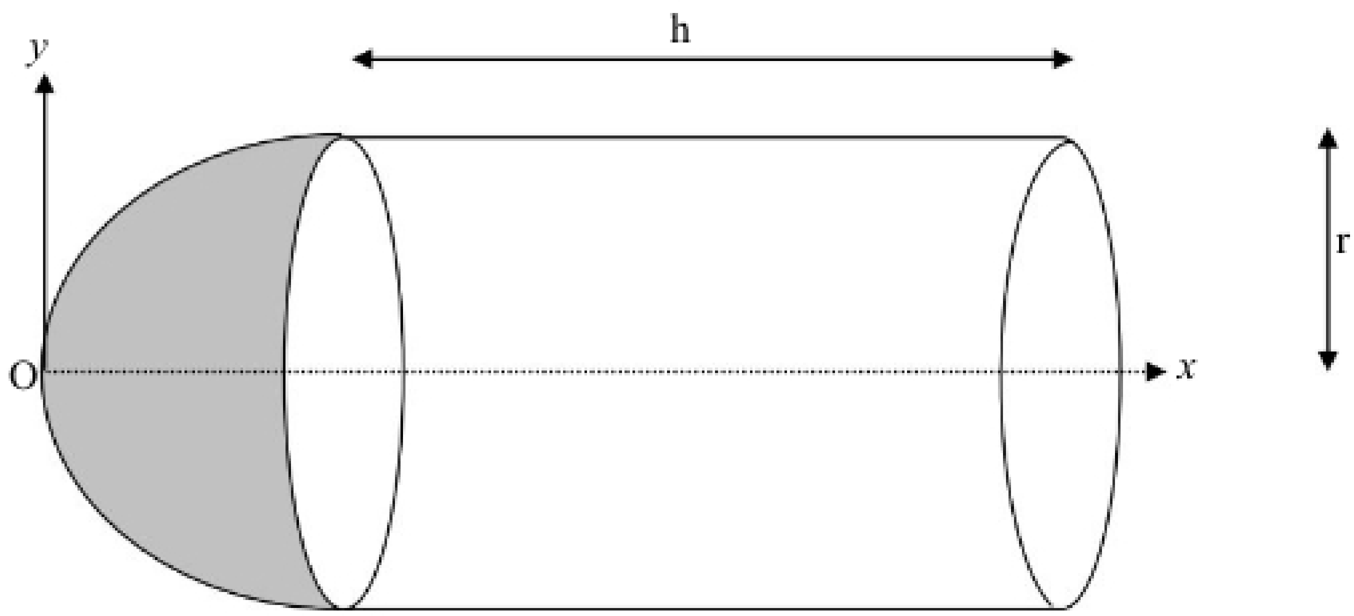
(a) Find the mass, in terms of ρ and π, of the solid cylinder and the coordinates of its centre of mass.

(b) Find the mass, in terms of ρ and π, of the cylindrical hole and the coordinates of its centre of mass.

(c) Find the coordinates of the centre of mass of the remainder.

[part 3–page 21]
(1 mark)

6.



A child's drinking cup is made from a uniform solid hemisphere of radius 3.00 cm surmounted by a uniform hollow cylinder of height h = 8.00 cm, as shown in the diagram The density ρ of the hemisphere is double the surface density σ of the cylinder.

(a) Find the coordinates of the centre of mass of the solid hemisphere.

[part 3–page 19]

(b) Find the coordinates of the centre of mass of the hollow cylinder.

[part 3–page 14]

(c) Find the mass of the hemisphere in terms of π and σ.

[part 3–page 19]

(d) Find the mass of the cylinder in terms of π and σ.

[part 3–page 14]

(e) Find the coordinates of the centre of mass of the composite body.

[part 3–page 21]
(2 marks)

7. Find the coordinates of the centre of mass of the solid formed when the finite region bounded by the curve with equation $y = \dfrac{1}{x}$, the lines $x = 1$ and $x = 2$ and the x–axis is rotated completely about the x–axis.

[part 3–page 23]
(1 mark)

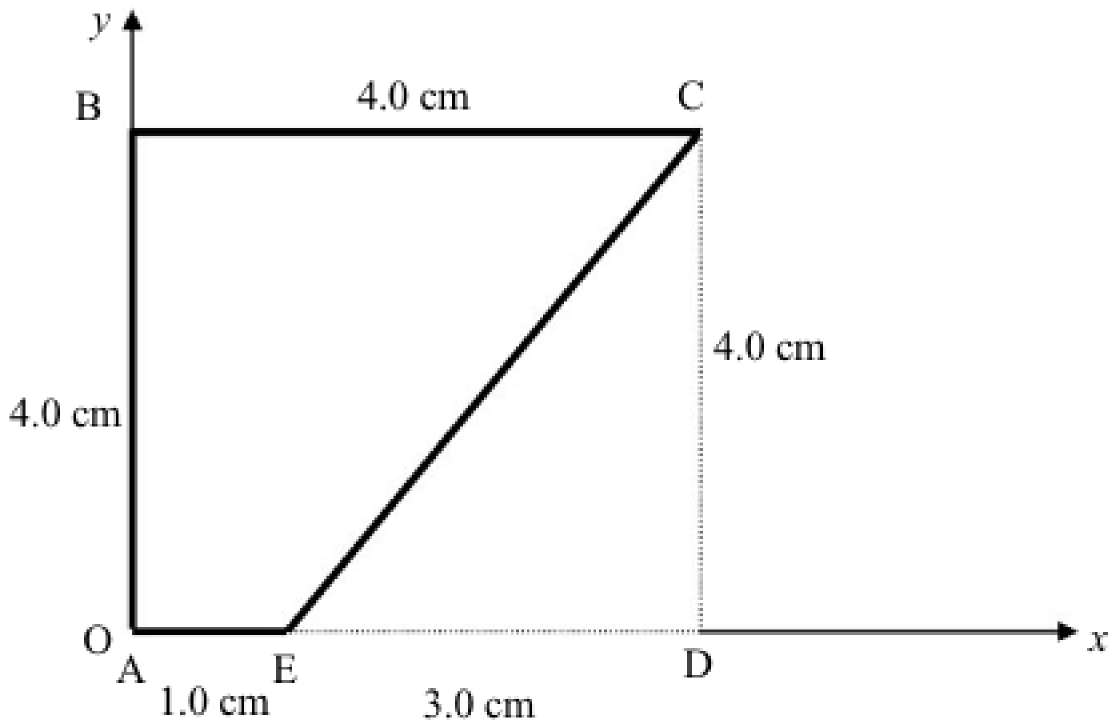
8. A uniform lamina is bounded by the curve with equation $y = x^3$, the x–axis and the lines $x = 1$ and $x = 2$.

(a) Find the x–coordinate of the lamina.

(b) Find the y–coordinate of the lamina.

[part 3–page 22]
(2 marks)

1.



A uniform square lamina ABCD has side 4.0 cm. The point E lies on AD and is such that ED = 3.0 cm. The triangle EDC is removed.

(a) Find the coordinates of the centre of mass of ABCD, and its mass.

[part 3–page 14]

(b) Find the coordinates of the centre of mass of EDC, and its mass.

[part 3–page 14]

(c) Find the *x*–coordinate of the centre of mass of the lamina ABCEA.

[part 3–page 21]

(d) Show that if the lamina is placed in a vertical plane with AE on a rough horizontal plane it will topple.

[part 3–page 25]

A mass m is placed at the corner B. The mass of ABCD is M.

(e) Find the moment of the weight of m about E.

[part 3–page 25]

(f) Find the mass of the lamina in terms of M.

[part 3–page 25]

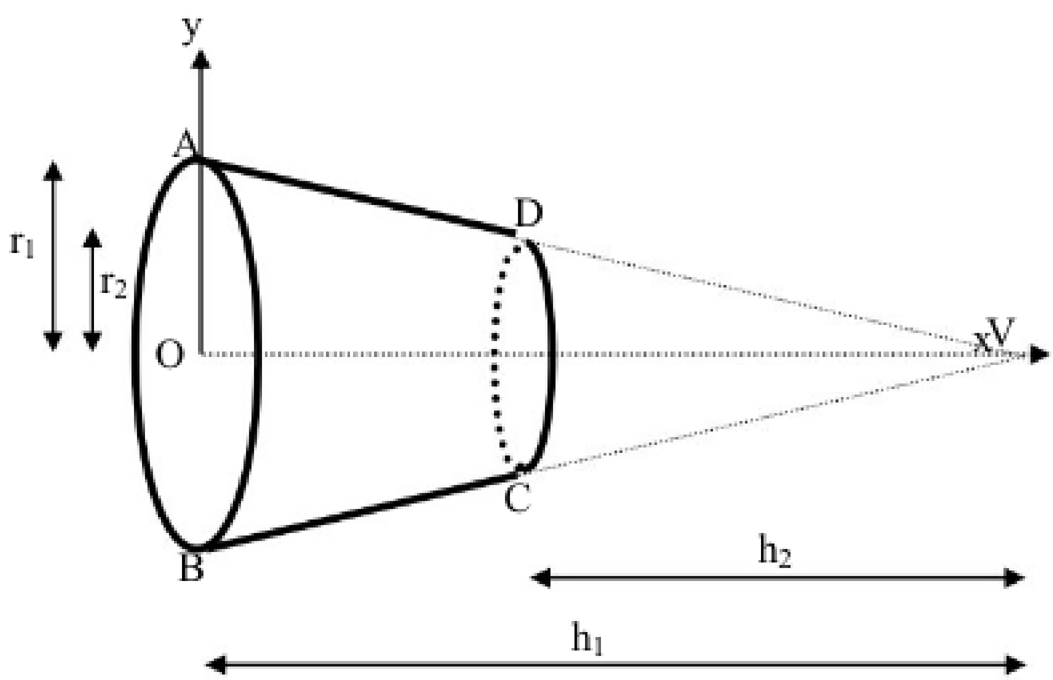
(g) Find the moment of the weight of the lamina about E.

[part 3–page 25]

(h) Find the smallest value of m as a fraction of M that will prevent toppling.

[part 3–page 25]
(2 marks)

2.



A uniform solid right circular cone has base radius $r_1 = 3.00$ m and height $h_1 = 4.00$ m. The top part of it, consisting of a small cone of base radius $r_2 = 1.50$ m and height $h_2 = 2.00$ m, is removed.

(a) Find the coordinates of the centre of mass of the large cone, and its mass in terms of ρ and π.

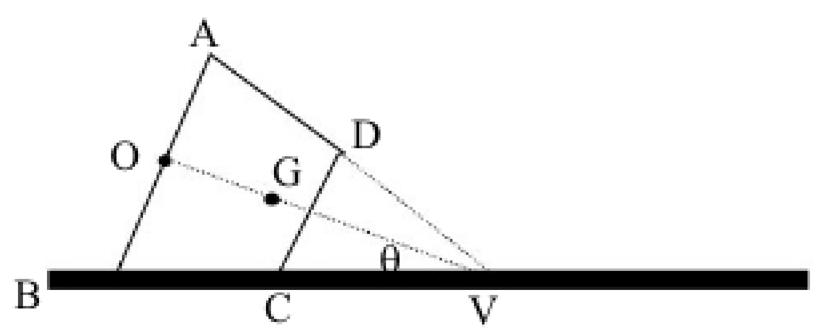
[part 3–page 18]

(b) Find the coordinates of the centre of mass of the small cone in the top part, and its mass in terms of ρ and π.

[part 3–page 18]

(c) Find the coordinates of the centre of mass of the frustum (the remaining part).

[part 3–page 21]



The frustum is placed with its curved surface in contact with a horizontal plane as shown in the diagram.

(d) Find the distance VC.

[part 3–page 25]

(e) Calculate the distance VG.

[part 3–page 25]

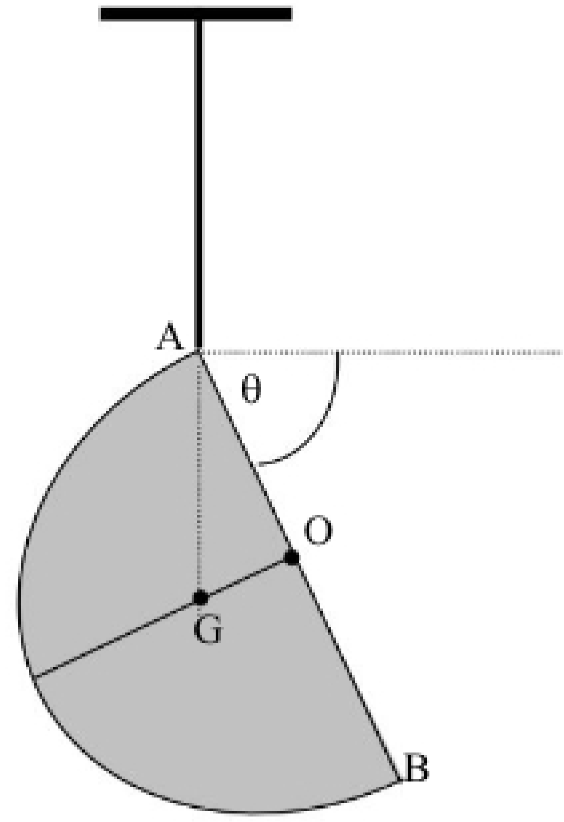
(f) GH is the perpendicular from G to BV. Find VH.

[part 3–page 25]

(g) Will the frustum rest in equilibrium?

[part 3–page 25]
(2 marks)

3.



A uniform solid hemisphere, of radius r, is suspended by a string attached to a point on the rim of its base as shown in the figure.

(a) Find the distance OG in terms of r.

[part 3–page 19]

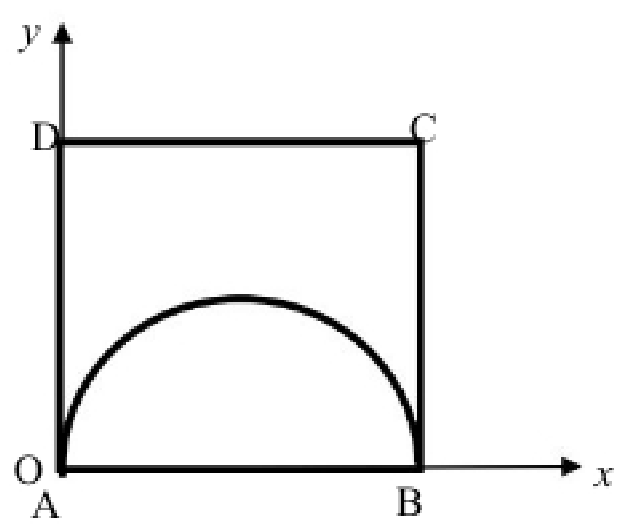
(b) Find $\tan\theta$, where θ is the angle between the horizontal and the plane face of the hemisphere when it is in equilibrium.

[part 3–page 25]

(c) Deduce the measure of θ.

[part 3–page 25]
(1 mark)

4.



A square lamina ABCD of side 4 cm is made of uniform thin material. A semicircular piece, with AB as diameter, is removed.

(a) Find the coordinates of the centre of mass of ABCD, and its mass in terms of σ.
[part 3–page 14]

(b) Find the coordinates of the centre of mass of the semicircular piece, and its mass in terms of σ and π.

[part 3‒page 16]

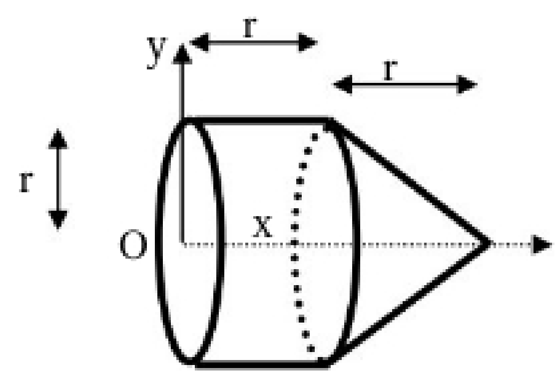
(c) Find the coordinates of the centre of mass of the remaining shape in terms of π.

[part 3‒page 21]

(d) The remaining shape is suspended by a string attached at C and hangs in equilibrium. Find $\tan\theta$ in terms of π, where θ is the angle between CD and the downward vertical.

[part 3‒page 25]
(2 marks)

5.



A solid uniform cylinder of radius r and length r has a solid uniform right circular cone, made from the same material, of base radius r and height r joined to it so that the base of the cone coincides with one end of the cylinder as shown in the figure.

(a) Find the coordinates of the centre of mass of the cylinder in terms of r, and its mass in terms of ρ, π and r.

[part 3‒page 14]

(b) Find the coordinates of the centre of mass of the cone in terms of r, and its mass in terms of ρ,π and r.

[part 3‒page 22]

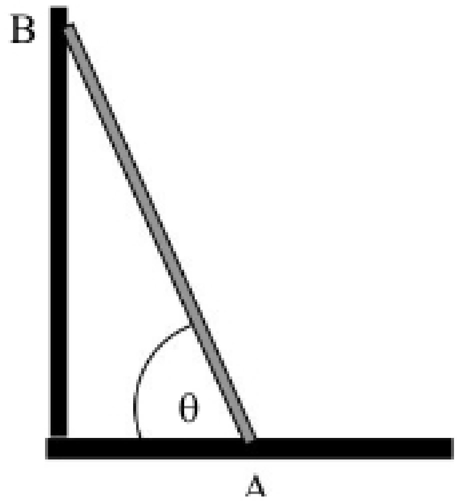
(c) Find the coordinates of the centre of mass of the composite body in terms of r.

[part 3‒page 21]

(d) The composite body is placed with its circular face on a rough plane which is inclined at an angle α to the horizontal. The plane is sufficiently rough to prevent sliding. Find $\tan\alpha$ for which the body is on the verge of toppling.

[part 3‒page 25]
(2 marks)

6.



A uniform ladder of mass 10.0 kg rests against a smooth vertical wall with its lower end on rough ground. The ladder rests in equilibrium at an angle $\theta = 60°$ to the horizontal.

(a) Calculate the magnitude of the normal contact force at the wall.

(b) Calculate the magnitude of the normal contact force at the ground.

(c) Calculate the magnitude of the frictional force at the ground.

(d) Obtain the least possible value of the coefficient of static friction.

[part 3–page 26]
(2 marks)

7. A uniform right circular cone of base radius a and height 6a rests in equilibrium with its base in contact with a rough inclined plane. The angle of inclination of the plane is then increased steadily. Assuming the plane is sufficiently rough to prevent slipping, find the angle (to 3 s.f.) of inclination of the plane to the horizontal when the cone is about to topple.

[part 3–page 25]
(1 mark)

Mechanics

Part 4

1. Assume the earth to be a sphere of radius 6.40×10^3 km and mass 6.00×10^{24} kg. An object of mass 80.0 kg is 600 km above the surface of the earth. ($G = 6.67 \times 10^{-11}$)

(a) Calculate the magnitude of the gravitational force on the object.

[part 4–page 36]

(b) Calculate the speed of the object if it is orbiting the earth at a constant height of 600 km above the surface.

[part 4–page 35]

(1 mark)

2. Assume the earth to be a sphere of radius 6.40×10^3 km and mass 6.00×10^{24} kg. ($G = 6.67 \times 10^{-11}$). A satellite is travelling in a circular orbit around the earth with a period of 24.0 hours. Find the height, in km, of the satellite above the earth's surface.

[part 4–page 36]

(1 mark)

3. A spacecraft is orbiting the moon at a constant height of 80.0 km. Assuming the moon to be a sphere of radius 1.74×10^3 km and mass 7.35×10^{22} kg, calculate the period of orbit of the spacecraft, in hours. ($G = 6.67 \times 10^{-11}$).

[part 4–page 36]

(1 mark)

4. Assume the earth to be a sphere of radius 6.40×10^3 km and mass $6.00 \text{ x } 10^{24}$ kg. ($G = 6.67 \times 10^{-11}$). A satellite takes 150 minutes to complete one circuit of the earth.

(a) Calculate the height of the satellite, in km, above the earth's surface.

(b) Find the speed of the satellite in km/s.

(c) Deduce the angular speed of the satellite.

[part 4–page 36]

(2 marks)

5. Assume the earth to be a sphere of radius 6.40×10^3 km and mass 6.00×10^{24} kg. ($G = 6.67 \times 10^{-11}$). Calculate the gain in the gravitational potential energy of a 4.00–kg mass if it is lifted from the surface of the earth to an altitude of 1.60×10^3 km.

[part 4–page 38]

(1 mark)

6. Assume the earth to be a sphere of radius 6.40×10^3 km and mass 6.00×10^{24} kg. ($G = 6.67 \times 10^{-11}$). A 50.0–kg satellite is orbiting the earth at an altitude of 1.60×10^3 km.

(a) What is the kinetic energy of the satellite?

[part 4–page 40]

(b) Calculate the total mechanical energy of the satellite.

[part 4–page 41]
(1 mark)

7. Assume the earth to be a sphere of radius 6.40×10^3 km and mass 6.00×10^{24} kg. ($G = 6.67 \times 10^{-11}$). A man of 75.0 kg is standing on the surface of the earth.

(a) What is the total mechanical energy of the man?

[part 4–page 41]

(b) What is the total mechanical energy of the man at an infinite distance from the earth?

[part 4–page 41]

(c) What is the binding energy of the man?

[part 4–page 42]

(d) What is the escape velocity of the man in km/s?

[part 4–page 44]

(e) What is the escape velocity of a 10.0–g pingpong ball in km/s?

[part 4–page 44]
(2 marks)

8. Assume the earth to be a sphere of radius $R_E = 6.40 \times 10^3$ km and mass 6.00×10^{24} kg. ($G = 6.67 \times 10^{-11}$). Consider a body of mass 5.00 kg.

(a) Find the gravitational potential at an altitude R_E above the surface of the earth.

(b) Find the gravitational potential at an altitude $2R_E$ above the surface of the earth.

(c) Deduce the energy, in MJ, required to lift the 5.00–kg body from an altitude R_E to an altitude $2R_E$ above the surface of the earth.

(d) If the 5.00–kg body is dropped from the altitude $2R_E$ find its speed, in km/s, when it reaches the altitude R_E.

[part 4–page 44]
(2 marks)

9. The orbit radius of the earth around the sun is 1.50×10^{11} m, and the orbit period is 365 days. Calculate Kepler's constant for the sun.

[part 4–page 35]
(1 mark)

Mechanics

Part 5

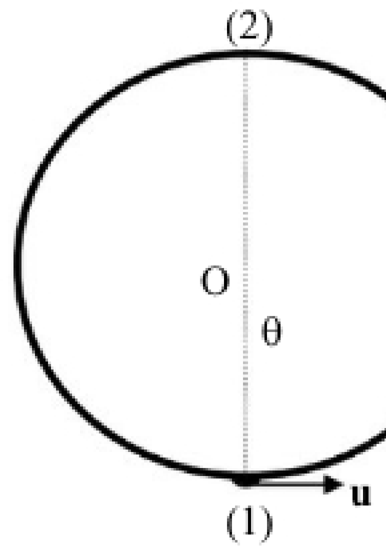
1. A particle of mass 500 g is attached to one end A of a light rod AB of length 20.0 cm which is free to rotate in a vertical plane about the other end B. The particle is held at rest vertically above B. It is slightly displaced so that it moves in a vertical circle.

(a) Calculate the speed of the particle as it passes through the lowest point of its path.

(b) Find the tension in the rod at this point.

[part 5–page 49]
(1 mark)

2.



A bead P threaded on a smooth circular wire of radius 50.0 cm and centre O which is fixed in a vertical plane as shown in the diagram. The bead is projected from the lowest point of the wire with a velocity **u**.

(a) Apply the principle of conservation of mechanical energy between points (1) and (2) to find the speed u for which the bead will describe complete circles.

(b) Given that $u^2 = 4.90$, apply the principle of conservation of mechanical energy between point (1) and (3) to find the angle between OP and the downward vertical at the highest point of P's path.

[part 5–page 49]
(2 marks)

3. A spring of natural length 75 cm and modulus 80 N is initially compressed to a length of 70 cm. It is then further compressed to a length of 50 cm. Calculate the increase in the energy stored in the spring.

[part 5–page 48]
(1 mark)

4. A particle of mass 1.50 kg is hanging in equilibrium at the free end of a light elastic string of natural length 2.00 m and modulus 16.0 N. The other end of the string is fixed. The particle is pulled downwards until the string has length 4.00 m. Calculate the increase in the elastic energy stored in the string.

[part 5–page 48]

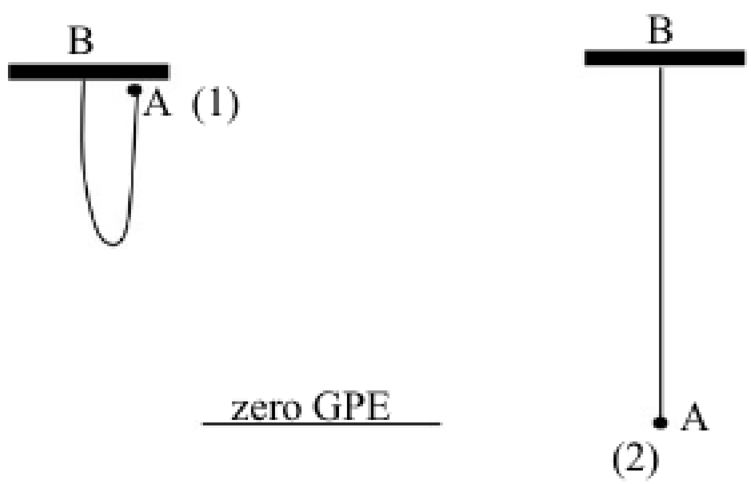
(1 mark)

5. A particle P of mass 2.00 kg is attached to one end of a light elastic string of natural length 160 cm and modulus 20.0 N. The other end of the string is fixed to a point O on a smooth horizontal table. P is released from rest at a point on the table 250 cm from O. Calculate the speed of P when the string becomes slack.

[part 5–page 48]

(1 mark)

6.



A particle of mass 500 g is attached to one end A of a light elastic string of natural length 100 cm and modulus 5.00 N. The other end B of the string is fixed to a point on a ceiling. The particle is held at B and then released as shown in the figure.

(a) Find the length of the string in the equilibrium position.

[part 1–page 5]

(b) Find the gravitational potential energy at position (1).

[part 5–page 48]

(c) Find the elastic potential energy at position (2) which is the equilibrium position.

[part 5–page 48]

(d) Use the principle of conservation of mechanical energy between positions (1) and (2) to find the speed of the particle when it passes through the equilibrium position.

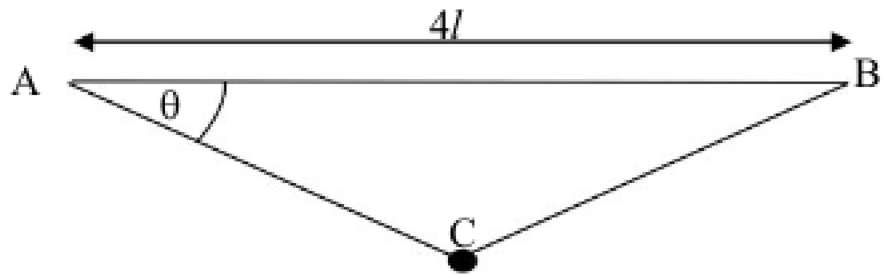
[part 5–page 48]

(2 marks)

7. A train of mass 120 tonnes is ascending an incline of 1 in 42 at a constant speed of 18.0 m/s. If the power being exerted by the engine is 810 kW, find the resistance to motion.

[part 5–page 47]
(1 mark)

8.



An elastic string of natural length $4l$ and modulus of elasticity 4mg is stretched between two points A and B which are on the same level, where AB = $4l$. A particle of mass M attached to the midpoint of the string hangs in equilibrium with both portions of string making an angle $\theta = 30.0°$ with AB.

(a) Calculate the length of AC in terms of l.

[trigonometry]

(b) Find the magnitude of the tension in each portion of string in terms of m and g.

[part 1–page 5]

(c) Calculate M in terms of m.

[Newton's 1st law]

(d) Find the elastic energy stored in the string in terms of m, g and l.

[part 5–page 48]
(1 mark)

9. Find the work done in stretching a rubber band round a roll of papers of radius 4.00 cm if the band when unstretched will just go round a cylinder of radius 2.00 cm and its modulus of elasticity is 0.500 N.

[part 5–page 48]
(1 mark)

10. An elastic spring of natural length 1.00 m and modulus 60.0 N rests on a smooth horizontal floor with one end fixed. A particle of mass 2.00 kg is attached to the free end of the spring which is compressed to a length of 0.750 m. The particle is released. Calculate the speed of the particle when the spring returns to its natural length.

[part 5–page 48]
(1 mark)

Mechanics

Part 6

1. (a) A particle of mass 5.0 kg is moving with velocity $(3.0\mathbf{i} + 4.0\mathbf{j})$ ms^{-1} when it is given an impulse $(-2.0\mathbf{i} + 6.0\mathbf{j})$ Ns^{-1}. Find the velocity of the particle after the impact.

(b) A particle of mass 0.500 kg is moving horizontally in a straight line with a speed of 20.0 ms^{-1}. It is hit by a bat, and moves back along its original path with a speed of 25.0 ms^{-1}. Find the magnitude of the impulse exerted on the particle by the bat.

[part 6–page 55]

(1 mark)

2. (a) Two particles P and Q of mass 2.0 kg and 3.0 kg respectively are moving towards each other along the same straight line with speeds 4.0 ms^{-1} and 5.0 ms^{-1} respectively. After the collision the particles coalesce. Find the speed of the combined particle after the collision.

(b) A particle of mass 0.5 kg is moving with velocity $(4\mathbf{i} + 7\mathbf{j})$ ms^{-1} when it strikes a fixed wall. It rebounds with velocity $(2\mathbf{i} + 3\mathbf{j})$ ms^{-1}. Find the impulse exerted on the particle by the wall.

[part 6–page 55]

(1 mark)

3. (a) A particle of mass 2.0 kg is falling at a speed of 12 ms^{-1} when it strikes the ground. The particle is brought to rest by the impact. Find the magnitude of the impulse exerted by the ground on the particle.

(b) Two particles P and Q of mass 4.0 kg and 2.0 kg respectively travel towards each other along the x–axis. The velocities of P and Q are $(6.0\mathbf{i})$ ms^{-1} and $(-2.0\mathbf{i})$ ms^{-1} respectively. The particles collide and after the collision Q has a velocity $(3.0\mathbf{i})$ ms^{-1}. Find the velocity of P after the collision.

[part 6–page 55]

(1 mark)

4. A particle of mass 3.00 kg falls from rest at a height of 5.00 m above a horizontal plane. It rebounds to a height of 3.00 m.

(a) Find the speed of the particle just before it hits the plane.

[part 5–page 46]

(b) Find the speed of the particle just after it leaves the plane.

[part 5–page 46]

(c) Calculate the magnitude of the impulse exerted on the particle by the plane.

[part 6–page 55]

(1 mark)

5. Two particles A and B of mass 0.2 kg and 0.5 kg respectively are moving towards each other along the same straight line on a smooth horizontal table. Particle A has speed 12 ms^{-1} and particle B has speed 2 ms^{-1}. Given that the coefficient of restitution between the particles is 0.5, find:

(a) the speeds of A and B after the impact,

[part 6–page 56]

(b) the magnitude of the impulse given to each particle.

[part 6–page 55]
(2 marks)

6. Two smooth spheres of equal radius have mass 2.5 kg and 1.5 kg respectively. They are travelling towards each other along the same straight line on a smooth horizontal plane. The heavier sphere has a speed of 3.0 ms^{-1} and the other sphere has a speed of 2.0 ms^{-1}. The spheres collide and after the collision the heavier sphere is at rest.

(a) Find the speed of the lighter sphere after the collision.

[part 6–page 55]

(b) Find the coefficient of restitution between the spheres.

[part 6–page 56]

(c) Find the kinetic energy lost in the collision.

[part 6–page 56]
(2 marks)

7. A small smooth ball falls from rest from a height of 135 cm above a fixed smooth horizontal plane. It rebounds to a height of 60.0 cm.

(a) Calculate the speed of the ball just before the impact with the plane.

[part 5–page 46]

(b) Calculate the speed of the ball just after the impact with the plane.

[part 5–page 46]

(c) Find the coefficient of restitution between the ball and the plane.

[part 6–page 56]
(1 mark)

8. A small smooth ball of mass 400 g is moving on a smooth horizontal table with a speed of 12.0 ms^{-1} when it collides normally with a fixed smooth vertical wall. It rebounds from the wall with a speed of 9.00 ms^{-1}.

(a) Find the coefficient of restitution between the ball and the wall.

(b) Find the kinetic energy lost by the ball due to the impact.

[part 6–page 56]
(1 mark)

9. Three particles A,B and C have mass 1.00 kg, 2.00 kg and 2.00 kg respectively. They lie in a straight line with B between A and C. The coefficient of restitution between any pair of these spheres is e. Initially B and C are at rest and A is projected towards B with speed 6.00 ms^{-1}. After collision A rebounds from B with speed 0.500 ms^{-1}.

(a) Find the speed of B after the first collision.

[part 6–page 55]

(b) Calculate the value of e.

[part 6–page 56]

(c) Find the speed of C after the second impact.

[part 6–page 56]
(2 marks)

Mechanics

Part 7

1. A particle P is moving along the line Ox with an acceleration $\frac{2}{3}t$ ms^{-2} at time t seconds. When t = 3.0 the speed of P is 4.0 ms^{-1} in the direction Ox and its displacement from O is 10 m.

(a) Find the speed of P at t = 0.

[part 7–page 60]

(b) Find the displacement of P from O when t = 6.0.

[part 7–page 61]
(1 mark)

2. A particle P is moving along the line Ox with an acceleration (6.0t – 18) ms^{-2} at time t seconds. When t = 0 the displacement of P from O is zero and its speed is 24 ms^{-1} in the direction Ox.

(a) Find the value of t when the particle first comes to instantaneous rest.

[part 7–page 60]

(b) Find the position of the particle when it first comes to rest.

[part 7–page 61]

(c) Find the position of the particle at t = 3.0 s.

[part 7–page 61]

(d) Find the distance travelled by the particle in the first 3.0 s.

[part 7–page 61]
(2 marks)

3. A particle P moves in a straight line with acceleration (cosπt) ms^{-2} at time t seconds. The particle starts from rest at the origin at t = 0.

(a) Find the velocity, in terms of π, of the particle at t = 0.50 s.

[part 7–page 60]

(b) Find the position of P, in terms of π, at t = 1.0 s.

[part 7–page 61]
(2 marks)

4. A particle P moves along Ox with an acceleration (e^{-t}) ms^{-2} at time t seconds. Given that at t = 0 the speed of P is 4.0 ms^{-1} in the direction Ox, and its displacement from O is 5.0 m.

(a) Find the velocity of P at t = 1.0 s.

[part 7–page 60]

(b) Find the displacement of P from O at t = 2.0 s.

[part 7–page 61]
(2 marks)

5. A particle P moves along the positive x–axis and its acceleration is $(3x)$ ms^{-2}, when its displacement from the origin O is x metres. Given that when $x = 0$ the velocity of P is 8.0 ms^{-1} in the direction Ox, find its velocity when $x = 1.0$ m.

[part 7–page 63]
(1 mark)

6. A particle P moves along the line Ox. When its displacement from O is x metres, its acceleration is of magnitude $\left(\frac{8}{x^2}\right)$ ms^{-2} and directed towards O. When $x = 1.0$ the velocity of P is 5.0 ms^{-1} in the direction Ox. Find the velocity of P when x = 0.50 m.

[part 7–page 63]
(1 mark)

7. The acceleration of a particle P, moving in a straight line, is $(4x^3)$ ms^{-2} when P has a displacement x metres from O, a fixed point in the line. The acceleration is away from O. Given that v = 2 when $x = 0$, obtain the value of x when v = 6.

[part 7–page 63]
(1 mark)

8. The acceleration of a particle P, starting from rest and moving in a straight line, is $\left(\frac{2}{3+v}\right)$ ms^{-2} when P has a velocity v ms^{-1}. Find its velocity at t = 4.0 s.

[part 7–page 61]
(1 mark)

9. The acceleration of a particle P, moving in a straight line, is (v^2) ms^{-2} when P has a velocity v ms^{-1}. Initially, v = 1.0 and x = 2.0 m.Find its position when v = e.

[part 7–page 61]
(1 mark)

Mechanics

Part 8

1. A particle P of mass 2.0 kg is moving along a straight line. P is initially at rest at a point O on the line. The force acting on P has magnitude $(3t^2 + e^t)$ N at time t s and acts in the direction OP. Calculate:

(a) the speed of P when t = 2.0.

(b) the distance OP when t = 4.0.

[part 8–page 66]
(2 marks)

2. A particle P of mass 500 g is moving in a straight line. When P is at a distance x m from a fixed point O on the line, the force acting on it is of magnitude $(6 - \cos 3x)$ N and acts in the direction OP. Given that P passes through O with speed 5.00 ms^{-1}, calculate the speed of P when $x = 2.00$.

[part 8–page 66]
(1 mark)

3. A particle P of mass 2.0 kg moves along the x–axis under the action of a force whose magnitude at time t s after P passes through the origin is (4 + 12t) N and which acts in the direction PO. P passes through O with a velocity 20 m/s. Calculate:

(a) the speed of P when t = 2.0.

(b) the displacement of P when t = 2.0.

(c) the time when P comes instantaneously to rest.

(d) the time when P returns to O.

[part 8–page 66]
(2 marks)

4. A particle P of mass 2.00 kg moves in a straight line under the action of the force $(-6v^3)$ N, v m/s being the velocity of P at t s. Initially P is at O, a fixed point on the line, with a velocity 2.00 m/s. Find:

(a) the velocity of P 3.00 s later.

(b) the displacement of P from O at 3.00 s.

[part 8–page 66]
(2 marks)

5. A particle P is moving along a straight line with simple harmonic motion of amplitude 0.500 m. It passes through the centre of the oscillation O with speed 5.00 m/s. Calculate :

(a) the period of the oscillation in terms of π.

(b) the speed of P when OP = 0.250 m.

[part 8–page 70]
(1 mark)

6. A particle is moving in a straight line with S.H.M. Its maximum speed is 5.00 m/s and its maximum acceleration is 12.0 m/s^2. Calculate:

(a) the period of the oscillation

(b) the amplitude.

[part 8–page 70]
(1 mark)

7. A particle P of mass 100 g is hanging in equilibrium attached to one end of a light elastic string of natural length 50.0 cm and modulus 5.00 N. The other end of the string is fixed. P is pulled dowmwards a further 20.0 cm and released. Calculate:

(a) the extension at the equilibrium position.

[part 8–page 72]

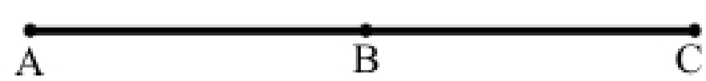
(b) the angular frequency of the motion.

[part 8–page 73]

(c) the time that elapses before the string becomes slack.

[part 8–page 73]
(2 marks)

8.



A particle of mass 2.00 kg is attached to one end of an elastic string of natural length 100 cm whose other end is fixed to a point A on a smooth horizontal plane. The particle is pulled across the plane to a point C where AC = 1.50 m and is released from rest at C as shown in the diagram. B is a point on AC such that AB = 1.00 m. If the modulus of the string is 10.0 N, calculate:

(a) the angular frequency of the motion.

(b) the time taken to travel from C to B.

(c) the speed of the particle at B.

[part 8–page 73]
(2 marks)

Chapter 21:

Student – Kinematics

1. A particle is moving such that: $x = 4t - 3$, $y = 3t^2 + 5$, $z = 7$ (where x, y and z are expressed in metres)

(a) Find the position vector as function of time.

(b) What is the initial position?

(c) Find the displacement between t = 1 s and t = 2 s.

(d) Find the magnitude of the displacement vector between t = 1 s and t = 2 s.

(e) Find the magnitude of the average velocity between t = 1 s and t = 2 s.

[part A–page 7]
(2 marks)

2. A particle is moving such that: $x = 2t^3 - 5t + 3$, $y = 3t^2 + 4t - 5$, $z = -t^3 + 2t^2 - 6$ (where x, y and z are expressed in metres).

(a) Find the velocity at t = 1 s.

[part A–page 8]

(b) Find the acceleration at t = 2 s.

[part A–page 9]

(c) Find the speed at t = 1 s.

[part A–page 8]

(d) Find the magnitude of the acceleration at t = 2 s.

[part A–page 9]
(2 marks)

3. A body moves along a straight line. Its position from the origin at time t is given by the equation: $x = 2t^2 - 8t + 5$, where x is in metres and t is in seconds.

(a) Determine the nature of the motion.

[part B–page 10]

(b) Find the average velocity of the body in the interval from t = 0 to t = 2 s.

[part A–page 7]

(c) Find the velocity at t = 2 s.

[part B–page 10]

(d) At what time does the particle pass through the origin?

[part B–page 10]
(2 marks)

4. The speed of a bus travelling due South is uniformly reduced from 54.0 km/h to 36.0 km/h in a distance of 62.5 m.

(a) What are the magnitude and direction of the acceleration?

(b) How long does it take to cover this distance?

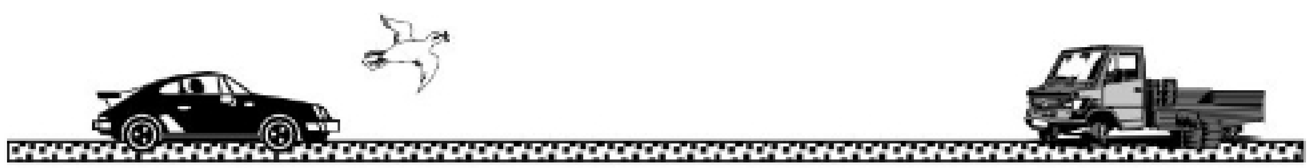
If the bus keeps decelerating at the same rate:

(c) how long does it take to come to rest from 54.0 km/h?

(d) what distance does it cover?

[part B–page 11]
(2 marks)

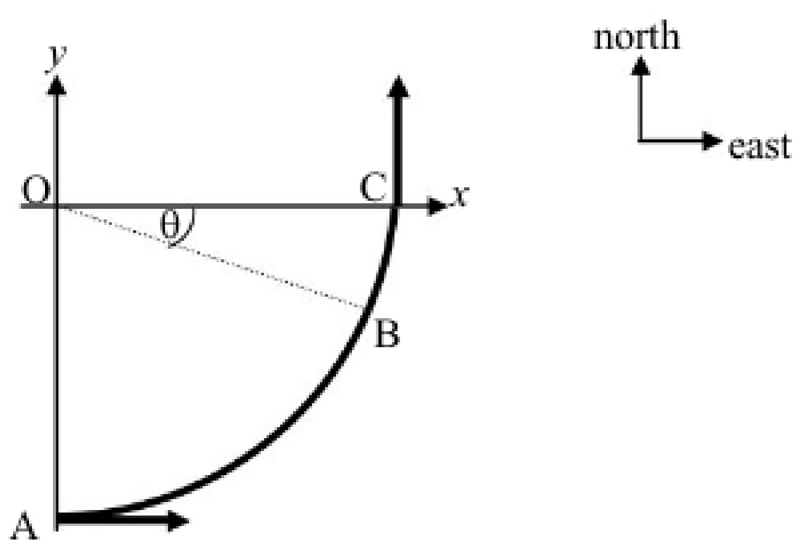
5.



A car travelling at 80 km/h directly toward a lorry travelling at 30 km/h. At the instant the vehicles are 55 km apart, a pigeon leaves the car, moving always with a constant speed of 48 km/h towards the lorry; on reaching the lorry, it flies straight back towards the car, and so on. What total distance will the pigeon cover before the vehicles meet?

[part C–page 13]
(1 mark)

6.



A car initially travelling eastward at A turns north by travelling in a circular path ABC at uniform speed as shown in the diagram. The length of the arc ABC is 235 m, and the car completes the turn in 36.0 s.

(a) Calculate the speed of the car.

[part D–page 17]

(b) Calculate the magnitude of the acceleration of the car.

[part D–page 18]

(c) Find the x component of the acceleration when $\theta = 35^0$.

[trigonometry]

(d) Find the y component of the acceleration when $\theta = 35^0$.

[trigonometry]
(2 marks)

7. At t = 0 a grinding wheel has an angular velocity of 24.0 rad/s. It has a constant angular acceleration of 30.0 rad/s^2 until a circuit breaker trips at t = 2.00 s.

(a) Calculate the angular velocity at t = 2.00 s.

(b) Through what angle did the wheel turn from t = 0 to t = 2.00 s?

From then on, it turns through 432 rad as it coasts to a stop at constant angular acceleration.

(c) Find the duration of this decelerating stage.

(d) What was its angular acceleration as it slowed down?

[part D–page 15]
(2 marks)

8. A particle is moving in a circle of radius 60.0 cm. It started from rest, with a uniform angular acceleration of 0.700 rads^{-2}.

(a) Calculate its angular velocity at t = 4.00 s.

[part D–page 16]

(b) Find the magnitude of the tangential component of the acceleration.

[part D–page 15]

(c) Find the magnitude of the normal component of the acceleration at t = 4.00 s.

[part D–page 18]

(d) Calculate the magnitude of the acceleration at t = 4.00 s.

[part D–page 18]
(1 mark)

9. The equation of motion of a particle is: $x_{cm} = 4\sin\left(8\pi t + \frac{\pi}{4}\right)$.

(a) Find the angular frequency, the period and the length of the line segment along which the motion occurs.

[part E–page 21]

(b) What is the velocity of the particle at time t?

[part E–page 19]

(c) Determine the position of the particle at $t = 0$.

[part E–page 19]

(d) Determine the velocity of the particle at $t = 0$.

[part E–page 19]

(e) What is the acceleration of the particle at time t?

[part E–page 19]

(f) What is the velocity of the particle at $x = \pm \sqrt{7}$ cm?

[part E–page 19]

(g) What is the maximum velocity of the particle?

[part E–page 19]
(2 marks)

10. A body moves in simple harmonic motion along a straight line of length 12 cm. At $t = 0$, the body is at one extremity of the trajectory (in the positive sense). The body makes eight complete oscillations per second.

(a) Write the equation of motion of the body.

[part E–page 21]

(b) Determine the velocity of the body at $t = 1/8$ s.

[part E–page 19]

(c) At what time does the body first pass through the position $x = +3$ cm?

[part E–page 19]
(2 marks)

11. A body moves in simple harmonic rotational motion of amplitude 3.0 revolutions and of frequency 1.5 Hz. At $t = 0$, $\theta = 3\pi$ radians.

(a) Determine the amplitude in radians.

(b) Find the angular frequency.

(c) What is the phase at $t = 0$?

(d) Determine the equation of motion.

(e) Find the angular velocity at time t.

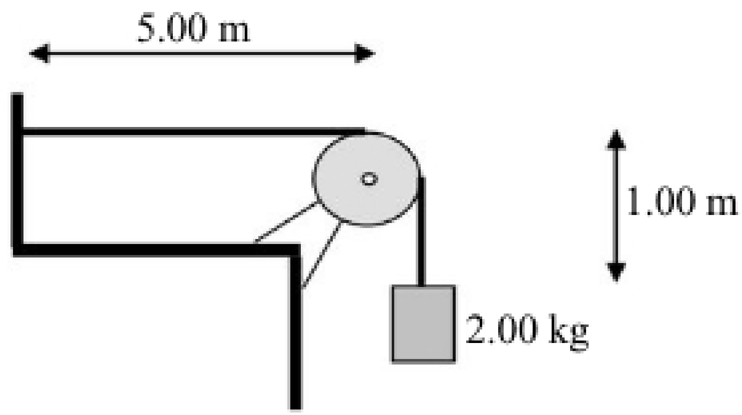
(f) Find the angular velocity at $t = 2.5$ s.

[part F–page 24]
(2 marks)

Chapter 15:

Mechanical Waves

1.



A uniform cord has a mass of 300 g and a length of 6.00 m as shown in the figure.

(a) Find the linear mass density of the cord.

(b) Find the speed of a pulse on this cord.

(c) Find the time it takes the pulse to travel from the wall to the pulley.

(1 mark)

2. A sinusoidal wave travelling in the positive x direction has an amplitude of 15.0 cm, a wavelength of 40.0 cm, and a frequency of 8.00 Hz. The vertical displacement of the medium at $t = 0$ and $x = 0$ is zero.

Find:

(a) the wave number.

(b) the period.

(c) the angular frequency.

(d) the speed of the wave.

(e) write a general expression for the wave function.

(f) write a general expression for the wave function if it were travelling in the negative x direction.

(2 marks)

3. A sinusoidal wave travelling in the positive x direction has an amplitude of 12.0 cm, a wave speed of 20.0 m/s, and a frequency of 5.00 Hz. The vertical displacement of the medium at $t = 0$ and $x = 0$ is zero.

(a) Write a general expression for the wave function.

(b) Calculate the maximum value of the transverse speed of any point on the string.

(c) Calculate the maximum value of the transverse acceleration of any point on the string.

(2 marks)

4. A string of mass 100 g is under tension of 80.0 N and has a wave speed of 40.0 m/s. Calculate its length.

(1 mark)

5. Transverse waves travel with a speed of 20.0 m/s in a string under a tension of 6.00 N. What tension is required for a wave speed of 30.0 m/s in the same string?

(1 mark)

6. A 30.0–m steel wire of density 7.86×10^3 kg/m^3 and a 20.0–m copper wire of density 8.92×10^3 kg/m^3, both with 1.00–mm diameters, are connected end to end and stretched to a tension of 150 N.

Calculate:

(a) the cross-sectional area of the wires.

(b) the linear mass density of the steel wire.

(c) the linear mass density of the copper wire.

(d) the speed of the wave in the steel wire.

(e) the speed of the wave in the copper wire.

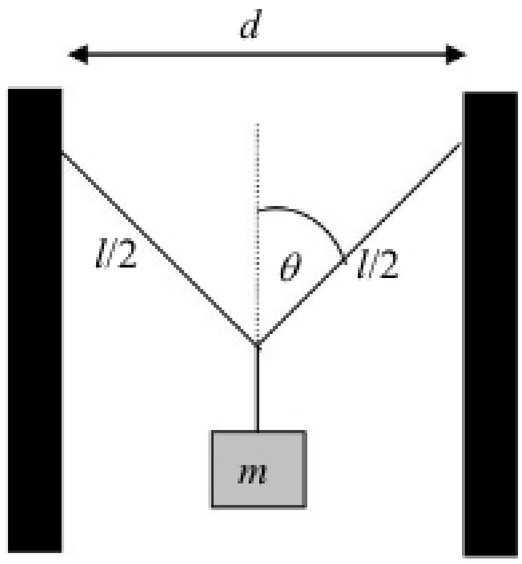
(f) the time it takes the wave to travel the length of the steel wire.

(g) the time it takes the wave to travel the length of the copper wire.

(h) the time it takes the wave to travel the entire length of the two wires.

(2 marks)

7.



A string of length l and mass per unit length 8.00 g/m has its ends tied to two walls separated by a distance d = $3l/4$. A mass m = 3.89 kg is suspended from the centre of the string putting a tension in the string.

(a) Find the measure of θ.

[trigonometry]

(b) Calculate the magnitude of the tension in the string.

[Newton's 1st law]

(c) Find the wave speed.

(2 marks)

8. (a) A sinusoidal wave is travelling along a rope. The oscillator that generates the wave completes 40.0 vibrations in 30.0 s. A given maximum travels 425 cm along the rope in 10.0 s. What is the wavelength?

(b) A bat can detect small objects such as an insect whose size is approximately equal to one wavelength of the sound the bat makes. If bats emit a chirp at a frequency of 60.0 kHz, and if the speed of sound in air is 340 m/s, what is the smallest insect a bat can detect?

(1 mark)

9. A wave travelling in the negative x direction and having equation $y = (4.0 \text{ cm}) \sin (2.0t + 3.0x)$, where x and y are in cm, reflects at a fixed end producing a standing wave.

(a) What is the equation of the reflected wave?

(b) What is the equation of the standing wave?

(c) What is the amplitude of the motion at $x = 2.3$ cm?

(d) Find the wavelength.

(e) How far from the fixed end is the second antinode?

(2 marks)

10. A middle C string of the C-major scale on a piano has a fundamental frequency of 264 Hz, and the A note has a fundamental frequency of 440 Hz.

(a) Calculate the frequencies of the next two harmonics of the C string.

(b) Calculate the frequencies of the 1st and 2nd overtones of the A string.

(c) If the strings for the A and C notes are assumed to have the same mass per unit length and the same length, determine the ratio of the tension in the A string to that in the C string.

(d) In a real piano, the assumption we made in part (b) is only half true. The string densities are equal, but the A string is 64.0 % as long as the C string. What is the ratio of their tensions?

(2 marks)

11. A standing wave is established in a 120-cm long string fixed at both ends. The string vibrates in four humps when driven at 120 Hz. Determine:

(a) the wavelength.

(b) the fundamental frequency.

(c) A stretched string is 160 cm long and has a linear density of 0.0150 g/cm. What tension in the string will result in a second harmonic of 460 Hz?

(1 mark)

12. A 60.0-cm guitar string under a tension of 50.0 N has a mass per unit length of 0.100 g/cm.

(a) What is the fundamental frequency?

(b) What is the order of the highest resonant frequency that can be heard by a person capable of hearing frequencies up to 20000 Hz?

(c) What is the highest resonant frequency, to 5 s.f., that can be heard by that person?

(1 mark)

Chapter 16:

Sound and Hearing

1. At a temperature of 127 °C, what is the speed of longitudinal waves in hydrogen of molar mass 2.02 g/mol, $\gamma = 1.41$, gas constant 8.31 SI?

(1 mark)

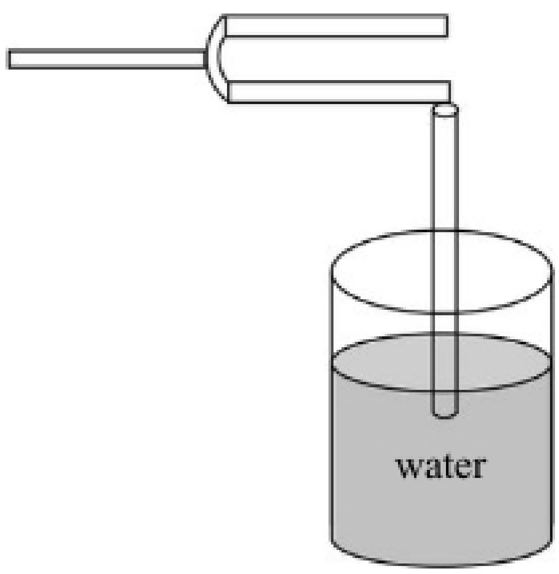
2. A pipe has a length of 1.23 m. Speed of sound in air = 343 m/s. Determine the frequency of the third harmonic if :

(a) the pipe is open at both ends.

(b) the pipe is closed at one end.

(1 mark)

3.



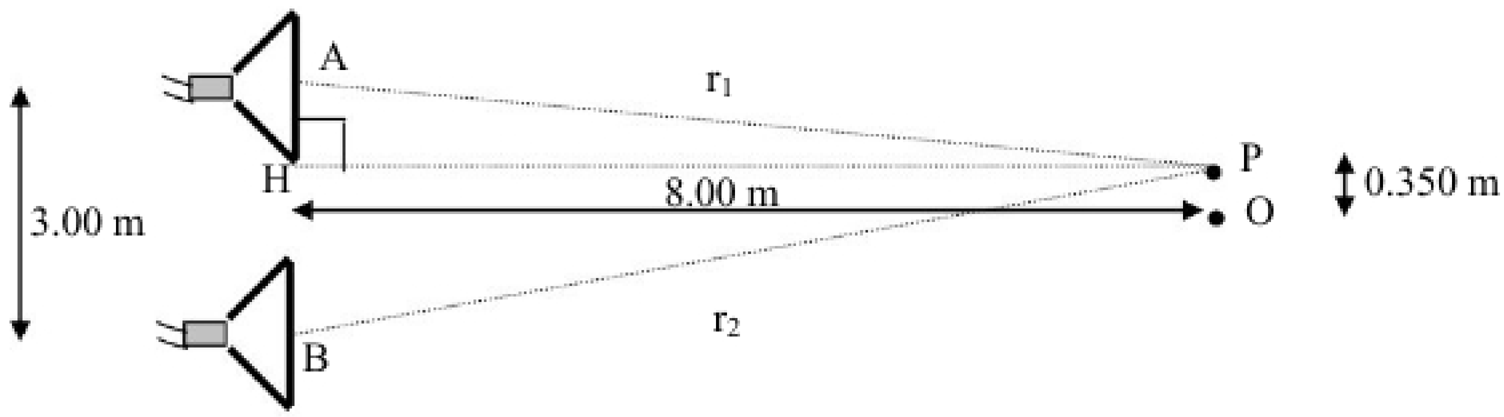
A simple apparatus for demonstrating resonance in a tube is described in the figure. A long, vertical tube open at both ends is partially submerged in a beaker of water, and a vibrating tuning fork of unknown frequency is placed near the top. The length of the air column, *l*, is adjusted by moving the tube vertically. The sound waves generated by the fork are reinforced when the length of the air column corresponds to one of the resonant frequencies of the tube. (speed of sound in air 343 m/s).
For a certain tube, the smallest value of *l* for which a peak occurs in the sound intensity is 9.00 cm. From this measurement, determine:

(a) the frequency of the tuning fork,

(b) the value of *l* for the next two resonant modes.

(2 marks)

4.



A pair of loudspeakers A and B placed 3.00 m apart are driven by the same oscillator as shown in the figure. A listener is originally at point O, which is located 8.00 m from the center of the line connecting the two speakers. The listener then walks to point P, which is a perpendicular distance 0.350 m from O before reaching the first minimum in sound intensity. Find:

(a) the distance AH

(b) the distance BH

(c) the distance PA

(d) the distance PB

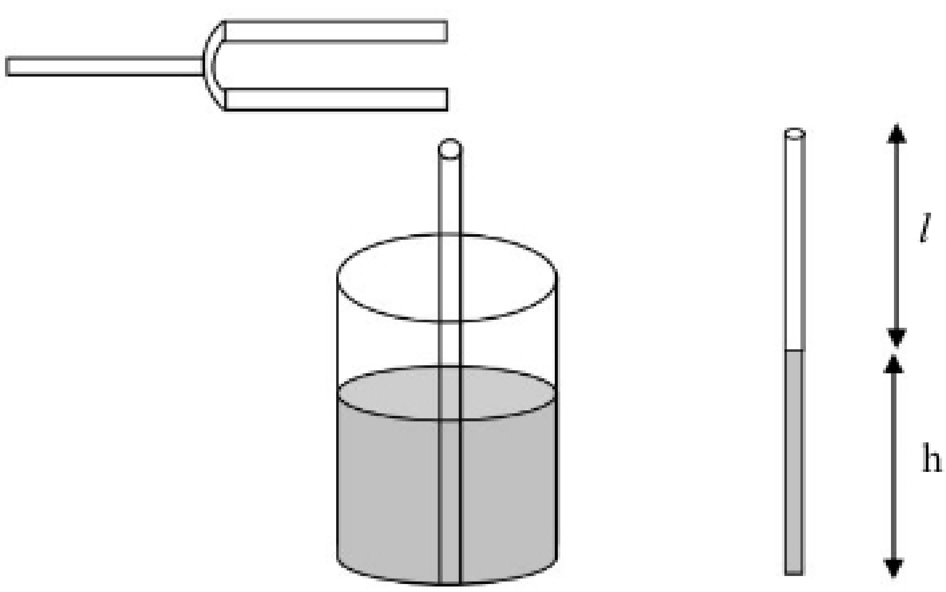
(e) the path difference $r_2 - r_1$

(f) the wavelength

(g) the frequency of the oscillator

(2 marks)

5.



An open pipe 40.0 cm in length is placed vertically in a cylindrical bucket having a bottom area of 0.100 m^2. Water is poured into the bucket until a sounding tuning fork of frequency 440 Hz, placed over the pipe, produces resonance as shown in the figure. (speed of sound in air 343 m/s).

(a) Find the length l of the pipe containing air.

(b) Deduce the height of water in the pipe.

(c) Find the mass of water in the bucket when resonance is produced.

(2 marks)

6. A train moving at a speed of 40.0 m/s sounds its whistle, which has a frequency of 500 Hz. Determine the frequency heard by a stationary observer as the train: (speed of sound in air 343 m/s).

(a) approaches the observer.

(b) recedes from the observer.

(1 mark)

7. An ambulance travels down a highway at a speed of 33.5 m/s. Its siren emits sound at a frequency of 400 Hz. What is the frequency heard by a passenger in a car travelling at 24.6 m/s in the opposite direction if the car is: (speed of sound in air 343 m/s).

(a) approaching the ambulance.

(b) receding from the ambulance.

(1 mark)

8. A student holds a tuning fork oscillating at 256 Hz. He walks toward his friend, standing beside a wall, at a constant speed of 1.33 m/s. (speed of sound in air 343 m/s).

(a) What frequency does his friend hear?

(b) What frequency does the student hear reflected from the wall?

(c) What beat frequency does the student hear between the tuning fork and its echo?

(d) If the student walks away from the wall at a constant speed of 3.38 m/s, what frequency does his friend hear?

(2 marks)

9. The sound source of a ship's sonar system operates at a frequency of 20.00 kHz. The speed of sound in water is 1500 m/s. A whale is travelling directly toward the stationary ship at 5.000 m/s.

(a) What is the wavelength of the waves emitted by the source?

(b) What frequency does the whale hear?

(c) What frequency is detected on the ship reflected from the whale?

(d) What is the difference in frequency between the directly radiated waves and the waves detected after reflection on the whale?

(2 marks)

10.

A carousel, 5.00 m in radius, has a pair of 600 Hz sirens, mounted on posts at opposite ends of a diameter. The carousel rotates with an angular velocity of 0.800 rad/s. A stationary listener is located at a distance from the carousel, as shown in the figure. The speed of sound in air is 350 m/s.

(a) Find the linear speed, in m/s, of the sirens.

(b) Find the maximum siren frequency heard by the listener.

(c) Find the minimum siren frequency heard by the listener.

(d) Find the maximum beat frequency of the sirens at the position of the listener.

(2 marks)

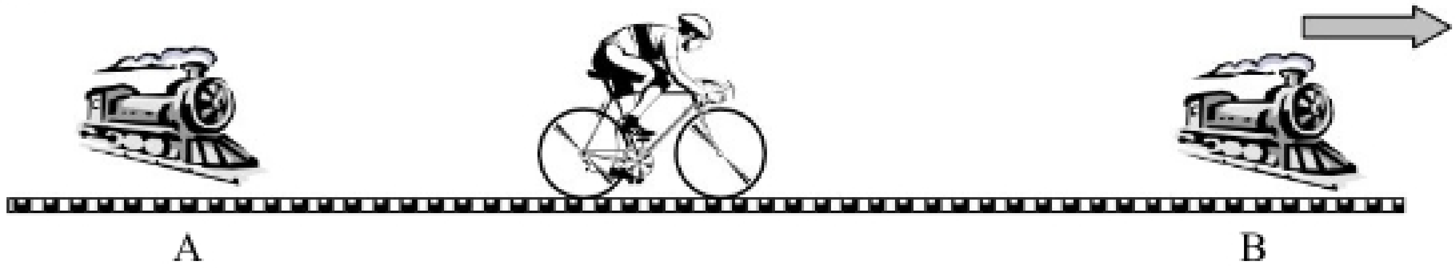
11. Two police cars have identical sirens that produce a frequency of 540 Hz. A stationary listener is standing between the two cars. One car is parked and the other is approaching the listener and both have their sirens on. The listener notices 6.00 beats per second. (The speed of sound in air is 340 m/s)

(a) Find the frequency of the sound coming from the approaching car as heard by the listener.

(b) Find the speed of the approaching police car.

(1 mark)

12.



Two train whistles, A and B, each have a frequency of 400 Hz. A is stationary and B is moving toward the right (away from A) at a speed of 40.0 m/s. A cyclist is between the two whistles and is moving toward the right with a speed of 20.0 m/s. (The speed of sound in air is 340 m/s).

(a) What is the frequency from A as heard by the cyclist?

(b) What is the frequency from B as heard by the cyclist?

(c) What is the beat frequency detected by the cyclist?

(d) If the cyclist comes to rest, what frequency does he hear from B?

(2 marks)

13. A railroad train is travelling at 26.0 m/s in still air. (Speed of sound in air is 344 m/s). The frequency of the note emitted by the locomotive whistle is 500 Hz. What is the wavelength of the sound waves:

(a) in front of the locomotive?

(b) behind the locomotive?

(1 mark)